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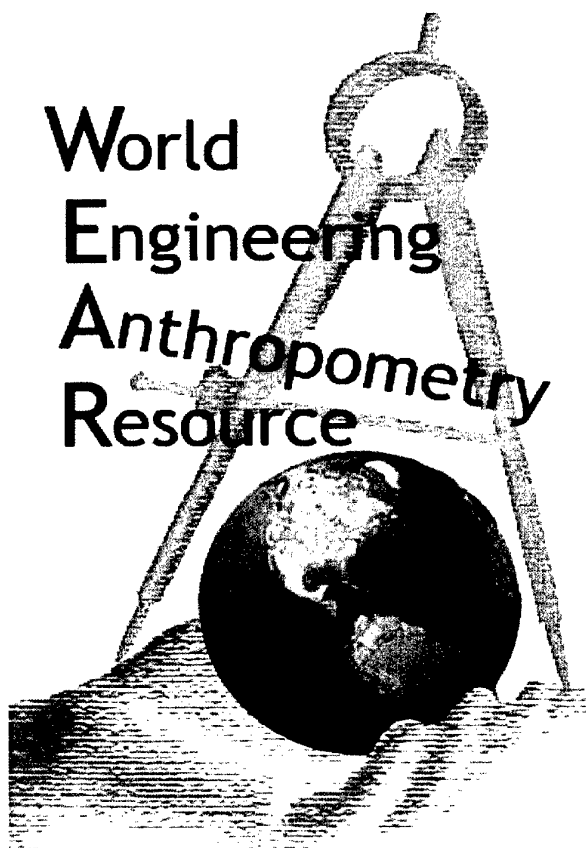
Université Paris 5

Laboratoire
d'Anthropologie
Appliquée

CENTRE UNIVERSITAIRE DES SAINTS-PERES

WORKSHOP 1

24-25 and 28 June 2002



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ACKNOWLEDGEMENTS

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- European Office of Aerospace Research and Development,*
- Air Force Office of Scientific Research,*
- United States Air Force Research Laboratory.*

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INTRODUCTION

The workshop 1 held in Paris was organized next to a first meeting held in Dayton-Ohio in September 2001.

The minutes of this first meeting are reported in annex.

The objective and the agenda of the workshop I are presented hereafter page 4 to 5.

The working group first reviewed the conclusions of the first meeting in Dayton. Then, further to an exchange on methods for data collection and data processing, a first description of the concept of WEAR was defined. The diagram presented page 6 summarizes this concept. Some examples of definitions for the components of the diagram are presented.

Each participant also joined the CARS 2002 Congress. The copy of the papers are presented page 9 to 48.

The copy of the PPT presentations are also joined : page 49 to 79.

A CD Rom of all presentations was distributed to each member of WEAR.

The issues of the workshop are :

- to add new members from South America, South Africa and Taiwan,
- to provide more definitions for the boxes of the WEAR diagram,
- to develop a Web site to exchange information and ideas,
- to organize a meeting in 2003 in Seoul (Korea) joined with the IEA Congress.

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WEAR WORKSHOP 1

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- List of participants.
- Background.
- Objective.
- Agenda.

WEAR

World Engineering Anthropometry Resource

Workshop 1

24-25 and 28 June 2002

Location of Meeting: - Salle Leduc (Ground Floor) Centre Universitaire des Saints-Pères
- Laboratoire d'Anthropologie Appliquée (7th Floor)
45 rue des Saints-Pères - 75006 PARIS

Sponsoring Organizations:

Université René Descartes-Paris 5
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BACKGROUND

The objective of the WEAR project is to identify and develop data models, software tools, theoretical constructs and principles that support the development of an on-line world-wide information system for utilizing the latest anthropometry databases in engineering environments. This system would include not only the latest 3D surface anthropometric data from all over the world, but also traditional anthropometric data, fit and accommodation information, analytic and software tools, and guidance or intelligent agents for using the information effectively. There are three basic research issues which must be addressed: 1) understanding the cognitive processes of an anthropometry expert when dealing with such databases, 2) identifying a means to computationally replicate these processes, and 3) characterizing huge populations of 3-D objects (human body scans) in a manner that can be effectively searched, mined and visualized. Such an information system would be able to be continually updated by registered users, and the information contained in it distributed throughout the world. This front-end study would determine the best potential technologies for replicating the experts and characterizing populations of 3-D objects in a systems approach that takes into account all of the other aspects and requirements of such a resource. New 3-D surface anthropometry data represents a valuable global resource if methods can be developed to exploit its potential.

Anthropometric data are collected and used by all types of organizations for many types of applications. These including universities, hospitals, health statistics departments, militaries, apparel companies, furniture manufacturers, automobile manufacturers, safety equipment companies, aerospace companies, and many other industries and organizations. Given the global nature of commerce most industries are interested in data from many countries, however, collecting this data is expensive. It would benefit everyone if the data collected by different organizations could be quickly and easily shared. We expect to be able to leverage evolving Web technologies for describing semantics such as XML Schema and RDF and to apply them to anthropometry. There are however, many challenges including: multiple data modalities; massive database size; lack of 3D object searching technology; measurement terminology differences; accessibility; ownership issues and many more. The technology needed to create such a system is spread throughout the world and across many disciplines. Furthermore, since the information system needs to be a worldwide resource it will be necessary to have participants throughout the world collaborate from the very start of the process.

OBJECTIVE OF THE WORKSHOP

This is an interdisciplinary workshop focused on anthropometrics and broad-based data sharing in this field. Topics include anthropometrics data itself, 3-D modeling of the human body, and database standardization to maximize utility.

During this workshop the WEAR Group would jointly prepare a document with recommendations for the international information system. The objective is to come up with a draft outline and perhaps a few notes about the document at the end of this workshop in Paris.

The participation at the CARS (Computer Assisted Radiology and Surgery) Conference on June 26 to 28, with a special session for the WEAR Group on June 28 Morning, will be an opportunity to get some feedback from the presentations of the members of the Group and to integrate remarks and needs from the medical imaging community concerning image information systems.

WEAR

World Engineering Anthropometry Resource

Workshop 1

AGENDA

Monday, June 24	17.00 h 19.30 h	Arrival: Welcome Meeting Dinner	R. Mollard
Tuesday, June 25	09.00 h 09.05 h 09.10 h 09.15 h 09.20 h 09.30 h 10.30 h 10.45 h 12.30 h 13.30 h 15.00 h 15.00 h 15.30 h 17.00 h 19.30 h	Call to Order Welcome Administrative Details Attendee Introductions Review Agenda Overview WEAR purpose and issues Coffee Break Create general outline of proposed report(s) on technology status and recommendations for WEAR lunch Discuss information system user needs Coffee Break Discuss information standardization issues Discuss information system contents issues Adjourn for day Dinner	R. Mollard D. Jore R. Mollard K. Robinette K. Robinette All All All All All
Friday, June 28	08.00 h 10.15 h 10.30 h 11.00 h 12.30 h 13.30 h 14.45 h 15.45 h 16.00 h 17.00 h	Paper Presentations at CARS conference Coffee Break Transfer to Centre Universitaire des Saints-Pères Discuss medical imaging contents, issues and lessons learned lunch Select authors for report chapters/sections Begin drafting sections Coffee Break Other business/future meetings Adjourn	All All All All K. Robinette

*We wish to thank the following for their contribution to the success of this conference:
European Office of Aerospace Research and Development, Air Force Office of Scientific Research,
United States Air Force Research Laboratory.*

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WEAR DIAGRAM

* * *

Examples of definitions

Input

0 END USERS

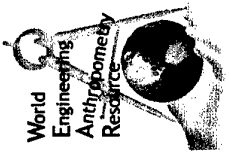
1 Tasks

2 Environment

3 Users
Origin
Sex
Educational level

4 Product
constraints

5 Life cycle
of the product
and delay
before production



I-wear
Ideal wear

[Http://ovrt.nist.gov/projects/WEAR](http://ovrt.nist.gov/projects/WEAR)

Online system

11 Private
database

6 Database in
1-D
3-D
raw data

12 User
action log

7 Visual index
Dictionary of
measurements
on morphology

8 Databases in
biomechanics
- joint
- strength
- motion
- visual field

9 Digital
Man Model
Tools

10 Definitions
Glossary + pictures
(domain of validity)

17 Standards

19 Ergonomic
guidelines

20 Estimate of
missing data

21 Statistical tools

Query tools

22 Measurement and
sample selection
Aid tool

23 Editor of results

13 Fit database

24 Statistical
Modeling
Secular trend

14 Fit scores database
linked to products

15 Digital
Products
Prototype

26 Maintenance and Update
of databases

18 Tutorials

25 Debate
forum

32 Off line
Tutorials - Workshop - End user working group

Output

27 Basic statistical results
1-D 3-D
Tables, mean, σ , histo...



28 Reports about
fit mapping

29 Population "customized"
Definition

30 3D models anatomical
1- reference points
2- arcs
3- surface IGES
4-individual scan data

31 Design criteria

WEAR
Workshop
Paris-June 2002

<p>21 Statistical tools ----- Query tools</p>	<p>Statistical tools: calculation of mean, standard deviation, percentiles, histogram, correlations, comparison, ellipses...</p> <p>Query tools: selection by survey, date, country, keywords, criteria on measurements (ex: stature\geq1800mm)...</p>
<p>27 Basic statistical results 1-D 3-D Tables, mean, σ, histo...</p> 	<p>Output of statistical tools</p> <ul style="list-style-type: none"> - table with mean, standard deviation, minimum, maximum, coefficient of variation (Pearson) - table with percentiles - table of correlation - table of contingency - histogram - ellipses - ...
<p>23 Editor of results</p>	<p>When you put a request on the database, you can choose some surveys and enter some criteria like sex, age or something like stature\geq1800mm if you want to study higher persons. Perhaps some of the surveys you have chosen don't have any subject corresponding to these criteria. This information is important as well as the data themselves, if you would like to notify the origin of your sample.</p> <p>After sample and measurement selection on the database, you need a tool to know which criteria have been used for the selection and the list of surveys and individuals that correspond to this query.</p> <p>The editor of results will output this information.</p>
<p>24 Statistical Modeling Secular trend</p>	<p>For each new product and design, you have to take into account the morphological evolution of population, or if you don't have enough recently measurements, you have to estimate this evolution.</p> <p>The statistical modeling secular trend will help you for this step</p>
<p>29 Population "customized" Definition</p> 	<p>Output of 24</p> <p>Graphics, estimation of evolution measurements...</p>



I-wear
Ideal wear

WEAR
Workshop
Paris-June 2002

<http://ovrt.nist.gov/projects/wear>

* * *

CONTRIBUTIONS OF THE WEAR GROUP TO CARS 2002

LIST OF PAPERS

* * *

R. MOLLARD. Shape modeling driven by the product design.

M.W. VANNIER, E. V. STAAB, L.C. CLARKE. Medical image archives - present and future.

Z. BEN AZOUZ, M. RIOUX, R. LEPAGE. 3D description of the human body shape: application of Karhunen-Loève expansion to the CAESAR database.

Y. LEE. Recent advances in Korean anthropometry.

M. MOCHIMARU, M. KOUCHI. Automatic shape modeling of the foot: towards a database of foot shapes.

S. RESSLER, Q. WANG. A Web3D based CAESAR viewer.

J.F.M. MOLENBROEK. Some tools for understanding anthropometry.

Shape modeling driven by the product design

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Abstract

After a review of the main characteristics of databases in anthropometry and ergonomics, and a short overview of the WEAR project, different approaches are presented to provide well-adapted information on human shape variability for the design of industrial products.

Keywords : Biostereometrics, database, ergodata.

1. Introduction

With the development of extensive networks like INTERNET, large databases have been developed in the different fields of technical and scientific information. Concerning ergonomics, the first steps concerned bibliographical databases gathering large amount of references. Simultaneously the development of more specific databases related to anthropometry and biomechanics was achieved. The purpose of these data systems was to create a tool for extracting main anthropometric data in a variety of useful forms and customizing the information to many different user needs. Pioneer works in the seventies were mainly the fact of the Human Engineering Laboratory from US-AMRL, USA [1] and the Laboratoire d'Anthropologie Appliquée from Université Paris V in EUROPE [2]. Based on a mutual exchange of surveys in anthropometry, these two teams created two international databases related to analysis of human morphology. Next steps for both parties and now for the World Engineering Anthropometry Resource (WEAR) Group are the data processing of 3-D anthropometry and biomechanics, and the development of more specific tools connected with Computer Aided Design softwares to provide well-adapted information for the design of industrial products.

This paper reviews general concepts for population databases in Ergonomics, with the example of ERGODATA, and some principles for the modeling of human shapes to include in a database system as proposed in the WEAR project.

2. Population databases in ergonomics

2.1 Principles for databases in anthropometry and ergonomics

A review of the needs in this field leads to an organization of the databases in nine main sections as shown in figure 1. Basically, traditional 1-D anthropometry is the most documented, thanks to the large amount of surveys available all around the world. Nowadays the other sections concern more limited samples, due to the difficulty of collecting experimental data, or to the lack of standardization in the methods for measurement or for data processing. Further to this classification, two kinds of databases can be applied to section 1 up to section 8 which are concerned with numerical data; section 9 being more related to bibliographical references. Those two kinds of databases are described in their principles in figure 2. The main differences originate in the types of input data:

- Individual Data (ID) using raw measurements on individual subjects from small or large surveys,
- Aggregate Data (AD) coming from results taken from articles, reports...

Both ID and AD databases are able to use a common dictionary for the definitions of measurements and are able to lead to the same results: statistical models of population. However one important point has to be mentioned concerning ID and AD databases:

- AD can easily be obtained from articles, proceedings, technical reports in the field of ergonomics. The results, then, only concern statistics, and post data processing is still limited.
- ID are more difficult to collect, but more powerful due to the possibilities to create new samples, using different criteria for sorting of data: age, sex, origin,... and to apply new processing adapted to a specific question. For example, sizing systems can be derived with quite a good accuracy from such data processing on ID, which is not possible with AD. Moreover, estimate of missing measurements can be obtained by using correlation matrix computed on ID. New measurements and indexes can also be calculated from ID.

ERGODATA was developed using this structure to provide basic data in the fields of anthropometry, biomechanics, and more generally ergonomics as well as statistical models of populations, with for instance a prediction of change in morphologies in the next 10-20 years [3],[4]. Individual Database (ID) and Aggregate Database (AD) in anthropometry contain worldwide surveys on various samples of subjects: males and females, civilians and military,... Specific databases were linked with ID and AD to collect and process experimental results on inertial properties, human strengths, as well as upper limb reach capabilities and movements for seated operators. Bibliographic data and documentary sheets on norms and recommendations in ergonomics are also available. A new database focused on 3-D surface anthropometry is now available. All this information may be used to create and animate digital human models. ERGOMAN was developed for this purpose. This digital man-model is dedicated to ergonomic analysis in a workplace design process: postural assessment, visual field, reach area capabilities. Shape modeling is also possible using dedicated softwares [5].

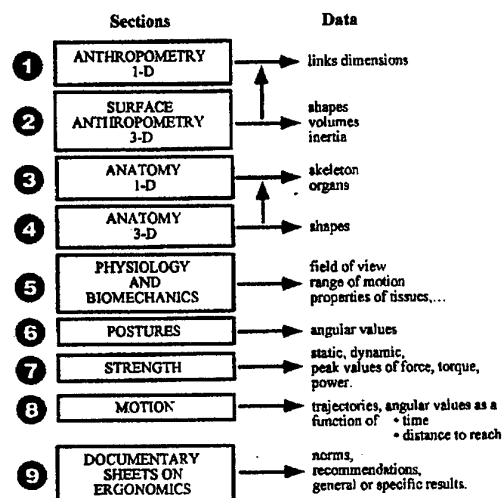


Figure 1. Main sections for population databases in ergonomics.

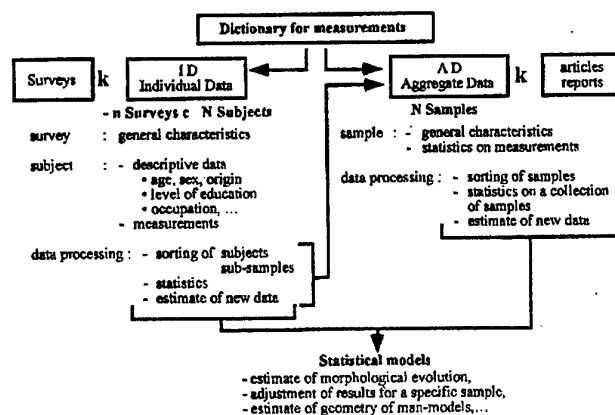


Figure 2. Principles used for Individual and Aggregate Databases.

2.2 WEAR project

The objective of the WEAR project is to identify and develop data models and software tools that support the development of an on-line world-wide information system for utilizing the latest anthropometry databases in engineering environments. This system would include not only the latest 3D surface anthropometric data from all over the world, but also traditional anthropometric data contained in existing databases, fit and accommodation information, analytic and software tools, and guidance or intelligent agents for using the information effectively. Three main research issues must be addressed: understanding the cognitive processes of an anthropometry expert when dealing with such databases, identifying a means to computationally replicate these processes, and characterizing populations of 3-D subjects in a manner that can be effectively searched, mined and visualized. Such an information system would be able to be continually updated by registered users, and the information contained in it distributed throughout the world. This front-end study would determine the best potential technologies for replicating the experts and characterizing populations of 3-D objects in a systems approach that takes into account all of the other aspects and requirements of such a resource. New 3-D surface anthropometry data represents a valuable global resource if methods can be developed to exploit its potential.

3. Shape modeling and product design

3.1 Anthropometric data processing

Different kinds of data processing can be achieved using, for instance, retrospective results from anthropometric surveys on specific samples or populations. A well documented example concerns the increase of the stature since the last 40-50 years. Based on the results taken from ID and AD databases, it is possible to determine the evolution of the mean values of stature for selected samples as well as for a global population [6]. Obviously the main difficulty to be solved is to get ensured that each sample is defined by the same criteria: sex, age, origin, sociocultural level,... An interesting result concerns the variability in morphology as well as in body proportions for the same samples of operators, but having different geographical origins. Another example is the choice of human body models to perform an ergonomical study using CAD technics. The main purpose is to define the amplitudes for adjusting the workplace according to postural, visual and reaching requirements of operators. So, the average operator is without interest. A better way to take into account is to define body dimensions of man-models according to the variability of lengths for key measures as eye-seat erected and buttock-knee length. A group of man-models can be easily derived if human variability can be modeled for these two measures. So, human proportions can be integrated as a criterion to define the working or the driving position. This can be performed using different man-models applications as ERGOMAN [4].

3.2 Biostereometric (3-D) data processing

With the availability of 3-D automatized measurement systems, new kinds of large surveys are now achieved by different teams all around the world. So, using 3-D data shape analysis is theoretically available. But in a practical manner, summarizing shape, for example for sizing, still remains a challenge [7, 8]. Other difficulties to be solved concern the relations with classical 1-D anthropometric data and the definition of reference postures and landmarks for 3-D data capture. In fact, we first have to face a standardization problem with 3-D measurements. Then, it is necessary to define a common manner to store these data and how to process them. This goal needs to be attained very rapidly in order to preserve some opportunities to compare results from surveys based on 3-D capture as CAESAR [9]. A proposal for standardization of procedure for databases on this specific topic have been pointed out during the workshop held in Paris last June (1998) (Workshop on 3-D Anthropometry and Industrial Products Design) but more work needs to be completed on this topic.

4. Shape modeling driven by the product

Modern rapid prototyping is marked by a large amount of creating procedures which can be done computer aided. However, to create a new product or to define a new workplace when man-machine-interface is a key issue, we need to describe human shapes related to the interface. Based on 3-D as well as 1-D anthropometric data, digital models can be derived. The main difficulties are to summarize human shapes in terms of variability. Sizing determination is necessary with generally "small", "medium" and "large" models. The main question is to select the criteria that characterize the small, medium or large models. For example, the design of an oxygen mask or a fore-face requires the determination of digital models of face and heads. As dimensions describing height, width and depth of the head are not related together (r less than .4), it is not possible to define a global model including, for instance, the 5th percentile values for all measures.

One of the way to solve the problem is to identify the key dimensions related to the product. This is the real first step for an ergonomical study. These key dimensions are retained as constraints and provide the range of variation for the anatomical area concerned by the interface with the product. Then the other criteria can be defined as a function of the fixed constraints. For example, in the design of a fore-face, the shape modeling will not necessarily concerns all the face. The frontal and lateral areas are more critical than the central area (eye, nose, month) and the digital model can be reduced (and simplified) to the anatomical areas related to the interface with the profile of the fore-face. Due to the constraints of stability and of protection, the frontal width and the curvature of the associated frontal anatomical area are the key dimensions, and the range of variations are provided by the deformability of the material retained by the designer to elaborate the product.

To summarize this approach, the main issue is to identify the geometrical zones of the product that will create the constraints. The digital model will necessary fit these constraints. The other areas are less critical. However the same approach needs to be replicate for these areas to identify the amplitude of variation which can be compensated

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or not by the profile. So, the number of sizes to fit the variability of the population will depend of these constraints.

The result of this methodology is the determination of simplified, but well-adapted, digital models of human shape, according to the identified needs of the users and the technical constraints of the designers.

References

1. Churchill, E, Churchill, T, Kikta, P.- AMRL Anthropometric Data Bank Library : Volumes I-V (AMRL-TR-77-I, AD A047 314) 1977.
2. Coblentz, A.- Une Banque de Données de Biométrie Humaine.- Conférence "On Advancements in Retrieval Technology as related to information systems". Arlington. 20-21 Octobre 1973.- Neuilly-Sur-Seine : AGARD.- pp. 8.8-8.14.- (AGARD C.P.P. 207).
3. Coblentz, A., Mollard, R., Hennion, P.Y., Vernay, J.- Ergodata: databases in anthropometry and ergonomics.- In: Proceedings of the International Conference on Occupational Safety Health Ergonomics & Environment, Wuhan (China) , September 9-15, 1997, pp. B47-B53.
4. Mollard, R., Hennion, P.Y., Vernay, J., Coblentz, A.- ERGODATA: a dedicated database system for digital human modeling and ergonomics studies.- SAE International "Digital human modeling for design and engineering. The Hague (Netherlands) 18-20 May, 2000, 8 p. (CD-ROM).
5. Coblentz, A., Mollard, R., Renaud, C.- ERGOMAN : 3-D representation of human operator and man-machine systems.- International Journal of Human Factors in Manufacturing, 1991, pp. 168-178.
6. Mollard, R., Hennion, P.Y., Coblentz, A.- Morphological evolution of French military personnels.- In: 44th Annual Meeting of the Human Factors Society, San Diego, July 30-August 4, 2000, pp. 6.774-6.747.
7. Coblentz, A., Mollard, R., Ignazi, G.- Three dimensional face shape analysis of french adults. Application for the conception of protective equipment.- Ergonomics, 34, 4, 1991, pp. 497-517.
8. Mollard, R.- Analyse des formes de la face à l'aide de mesures 1-D et 3-D.- In : Journées d'études Anthropométrie 3-D et Conception de produits industriels, Paris, 25-26 Juin 1998, pp. 16-1/16-8.
9. Robinette, K.M.- CAESAR 3-D Anthropometric Database. The Civilian American and European Surface Anthropometry (CAESAR) project.- In : Proceedings of Workshop on 3D anthropometry and Industrial Products Design, Paris (France), June 25-26, 1998, pp. 18-1/18-3.

Medical image archives – present and future

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Abstract

Repositories, data warehouses, public archives, and multimedia databases, especially those containing images, are important for clinical practice, education, and research in medicine. Imaging modalities, such as digital radiography, computed tomography, ultrasonography, nuclear medicine, digital angiography and magnetic resonance imaging produce large amounts of data that are managed, archived, and reported using picture archiving and communications systems (PACS) in an integrated healthcare enterprise (IHE) infrastructure. The technology and applications of PACS and IHE are well understood and widely available worldwide.

However, typical PACS and IHE systems are closed to ensure privacy, security and confidentiality. Sharing of medical image databases is relatively new, despite the widespread prevalence of open public archives for other types of biological data, especially in genomics and proteomics. Bioinformatics often implies that sequence and not image information is the focus of interest. Medical image visualization, analysis and measurement are widely used, and should continue to grow in importance as computer and display technology continues to evolve.

The principles of medical image archives, repositories, data warehouses, and multimedia databases will be reviewed. The applications of publicly available data sets include research, both basic and clinically applied, on the development, testing and standardization of algorithms and heuristics for computer assisted diagnosis, for example. Data mining of clinical databases, especially those richly invested with images, may be beneficial in producing quantitative image-based metrics and biomarkers for disease presence, staging, treatment selection and planning, prognosis, and monitoring. The technical requirements for construction of publicly accessible medical image archives that are well suited to exploratory data analysis, synthesis and testing of diagnostic and prognostic quantitative image analysis methods, biomarker and surrogate endpoint testing, and computer aided diagnosis will be outlined.

Regulatory requirements for testing of quantitative medical image-based analysis methods are in development. The FDA requirements for electronic submission and review of medical image analysis devices will be described, and their impact on the technical requirements for publicly accessible medical image archives will be delineated.

Keywords: Archive, image database, research resource

1. Introduction

Public libraries of printed works have evolved into open access repositories of documents, images, and media, sometimes known as digital libraries. [1] Molecular biologists share genome and related data in digital form on open access servers with portable open source software tools. [2] Biomedical signal databases have been constructed for open access to the academic community. [3] Recently, the concept of shared results from medical research has expanded beyond sequence information to include all forms of data that may be reused by other investigators. The successes of the molecular biology infrastructure are well known. It has provided the means for experts in computer science, mathematics and statistics to make significant contributions to this field from which, without the infrastructure, most of them would have been excluded. These successes are not necessarily unique to molecular biology, and the Biomedical Informatics Research Network (BIRN) initiative is aimed at building upon them and extending them to a wider set of biomedical research arenas. [4] In March 2002, the National Institutes of Health announced its data sharing policy, scheduled for implementation in 2003. [5] There are numerous shared medical image archive projects underway, notably the National Cancer Institute's Lung Image Database Consortium (LIDC) [6], RSNA Medical Imaging Resource Center (MIRC) [7], and other image repositories that will be introduced in this paper.

2. Medical image access policy

Access to medical images stored in repositories is essential for investigators who do not possess the resources to collect data of their own, for standardized comparisons of image analysis methods tested with the same input data, for regulatory approval of new medical devices, to develop new methods, and potentially for use in clinical decision support. Recently, new data sharing policies have been developed that govern access to medical data, including images.

2.1 NIH data sharing policy

Data sharing promotes many goals of the National Institutes of Health's (NIH) research endeavor. It is particularly important for unique data that cannot be readily replicated. Data sharing allows scientists to expedite the translation of research results into knowledge, products, and procedures to improve human health. The NIH is developing a statement on data sharing that expects and supports the timely release and sharing of final research data from NIH-supported studies for use by other researchers. Investigators submitting an NIH application will be required to include a plan for data sharing or explain why data sharing is not possible. This statement will apply to extramural scientists seeking grants, cooperative agreements, and contracts as well as intramural investigators. [5]

2.2 Background

There are many reasons to share data from NIH-supported studies. Sharing data reinforces open scientific inquiry, encourages diversity of analysis and opinion, promotes new research, makes possible the testing of new or alternative hypotheses and methods of

analysis, supports studies on data collection methods and measurement, facilitates the education of new researchers, enables the exploration of topics not envisioned by the initial investigators, and permits the creation of new data sets when data from multiple sources are combined. By avoiding the duplication of expensive data collection activities, the NIH is able to support more investigators than it could if similar data had to be collected *de novo* by each applicant.

NIH-supported basic research, clinical studies, surveys, and other types of research produce data that may be shared. However, NIH recognizes that sharing data about human research subjects presents special challenges. The rights and privacy of people who participate in NIH-sponsored research must be protected at all times. Thus, data intended for broader use should be free of identifiers that would permit linkages to individual research participants and variables that could lead to deductive disclosure of individual subjects. Similarly, NIH recognizes the need to protect patentable and other proprietary data and the restriction on data sharing that may be imposed by agreements with third parties. It is not the intent of this statement to discourage, impede, or prohibit the development of commercial products from federally funded research.

There are many ways to share data. Sometimes data are included in publications. Investigators may distribute data under their own auspices. Some investigators have placed data sets in public archives while others have put data on a web site, building in protections for privacy through the software while allowing analysis of the data. Restricted access data centers or data enclaves facilitate analyses of data too sensitive to share through other means. All of these options achieve the goals of data sharing. A web-based image archive was developed at the NIH Center for Information Technology to support data sharing. [8] However, the NIH also recognizes that in some particular instances sharing data may not be feasible. For example, studies with very small samples or those collecting particularly sensitive data should be shared only if stringent safeguards exist to ensure confidentiality and protect the identity of subjects while recognizing the contribution of the investigators who designed the protocol and collected the data.

2.3 National Cancer Institute - Biomedical Imaging Program (BIP)

The National Cancer Institute (NCI) is the component of the NIH that investigates, develops and applies new methods for patients with cancer. The Biomedical Imaging Program (BIP) in the Division of Cancer Treatment and Diagnosis at NCI is the principal resource for oncologic imaging for the full range of applications from the molecular level to intact patient. The NCI BIP funds the American College of Radiology Imaging Network (ACRIN) to conduct multicenter trials of cancer imaging.

2.3.1 ACRIN image access policy

ACRIN archives the images collected in cancer clinical imaging trials under its protocols. For example, the Diagnostic Mammographic Imaging Screening Trial (DMIST, <http://www.dmist.org>) will collect digital mammograms from almost 50,000 patients and place all of the data in an electronic archive. ACRIN has developed a policy under NCI guidance for sharing data after completion of its clinical trials, by allowing access to qualified investigators who were not involved in recruiting subjects or performing examinations. [9]

2.3.2 Lung Imaging Database Consortium (LIDC)

Preliminary clinical studies show that spiral CT scanning of the lungs can improve early detection of lung cancer in high-risk individuals. However, more clinical data are needed before public health recommendations can be made for population-based screening. Image processing algorithms have the potential to assist in lesion detection and characterization on spiral CT studies, and to assess the stability or change in lesion size on serial CT studies. The use of such computer-assisted algorithms could significantly enhance the sensitivity and specificity of spiral CT lung screening, as well as lower costs by reducing physician time needed for interpretation. The LIDC initiative [6] receives BIP support for a consortium of five institutions to develop consensus guidelines for a spiral CT lung image resource and to construct a database of spiral CT lung images. The investigators funded under this initiative will create a set of guidelines and metrics for database use and develop a database as a test-bed and showcase for those methods. The database will be available to researchers and users through the Internet and will have wide utility as a research resource.

2.3.3 BIP image archive advisory committee and workshops

An advisory committee met for workshops in 2000 and 2001 [9,10] to advise the BIP on the need, feasibility and approach to a common archival system for storing and accessing imaging databases by the broad scientific community. This work continues with open communications to all interested parties through a public moderated listserver, archive-comm-1 at <http://list.nih.gov>. Comments on this paper and related matters are encouraged and may be entered in the listserver by sending e-mail to archive-comm-1@list.nih.gov

3.0 Medical image archives

Several important initiatives are underway to assemble and distribute medical image data to investigators to develop and test new post-processing and visualization methods. A searchable list of websites for archives is available through the University of California at San Diego at <http://odwin.ucsd.edu/idata/>

3.1 BIRN – Biomedical Imaging Research Network

The BIRN is an NIH National Center for Research Resources (NCRR) initiative aimed at creating a testbed to address biomedical researchers' need to access and analyze data at a variety of levels of aggregation located at diverse sites throughout the USA. [4] The BIRN testbed will bring together hardware and develop software necessary for a scalable network of databases and computational resources. Issues of user authentication, data integrity, security, and data ownership will also be addressed.

The plan for the testbed is to focus on research involving neuroimaging to take advantage of the relatively advanced level of sophistication of this community in the use of information technology. An essential feature of the testbed will be creation of infrastructure that can be deployed rapidly at other research centers throughout the country, that may have research emphases outside of neuroimaging. This means that in addition to scalability, the software/hardware must be reusable and extensible.

The BIRN testbed will draw heavily on resources of the next generation internet that is funded by the National Science Foundation for both design and implementation. The

initial awards join General Clinical Research Centers and co-located Biomedical Technology Research Resources to establish the necessary infrastructure in the context of ongoing neuroimaging research projects. Support for "system integrators" that coordinate network, grid, and data mining software development as well as hardware configurations will be awarded to a recognized leader in such technical development and service efforts.

To contain the scope of the testbed, the BIRN initiative is initially focused on neuroimaging and is supporting several virtual neuroimaging research centers, each of which spans multiple leading academic and clinical institutions.

3.2 Craniofacial image archive

The Craniofacial Imaging Laboratory at the Cleft Palate and Craniofacial Deformities Institute, St. Louis Children's Hospital, Washington University Medical Center, has developed an electronic archive for the storage of computed tomography image digital data that is independent of scanner hardware and independent of units of storage media (i.e., floppy disks and optical disks). [12] The archive represents one of the largest repositories of high-quality computed tomography data of children with craniofacial deformities in the world. Archiving reconstructed image data is essential for comparative imaging, surgical simulation, quantitative analysis, and use with solid model fabrication (e.g., stereolithography). One tertiary craniofacial center's experience in the establishment and maintenance of such an archive through three generations of storage technology is reported. The current archive is housed on an external 35-GB hard drive attached to a Windows-based desktop server. Data in the archive were categorized by specific demographics into groups of patients, number of scans, and diagnoses.

The Craniofacial Imaging Laboratory archive currently contains computed tomography image digital data for 1827 individual scans. Storage of CT image data in a digital archive allows for continuous upgrading of image display and analysis software and facilitates longitudinal and cross-sectional studies. Internet access for clinical and research purposes is feasible, contingent on protection of patient confidentiality and investigator's rights or recognition.

3.3 Radiology teaching files and RSNA's MIRC

The importance of electronic images for teaching medicine and especially radiology has been enhanced by linkage to PACS [13] and the AFIP collection. [14] The Radiological Society of North America (RSNA) is developing a Medical Imaging Resource Center (MIRC). The goal is to develop a central repository for medical images, as well as related text, in support of projects related to research, education, and clinical care. PACS vendors should provide much more sophisticated tools to create and annotate teaching file images in an easy to use but standard format (possibly RSNA's MIRC format) that could be exchanged with other sites and other vendors' PAC systems. The privilege to create teaching or conference files should be given to the individual radiologists, technologists, and other users, and an audit should be kept of who has created these files, as well as keep track of who has accessed the files. Vendors should maintain a local PACS library of image quality phantoms, normal variants, and interesting cases and should have the capability of accessing central image repositories such as the RSNA's MIRC images.

4. Conclusion

Sharing medical image data on public repositories is expected to facilitate the development of image analysis tools and results. Several examples of new policy guidelines for electronic access to images from repositories were given to illustrate how these archives are organized and operated. Many more examples exist, and new medical image archive initiatives are announced each year. In time, we can measure the impact of this fundamental change in the culture of medical imaging research. Importantly, the current format standard for this data is DICOM [15], and electronic images may be useful for regulatory purposes in FDA review of new drugs and devices. [16]

References

1. Nadkarni PM. Information retrieval in medicine: overview and applications. *J Postgrad Med* 2000 Apr-Jun;46(2):116-22.
2. Entrez at <http://www.ncbi.nlm.nih.gov/Database/>
3. A. Cohen and I. Korhonen, eds. Biomedical Signal Databases, special issue of *IEEE Engineering in Medicine and Biology Magazine* (20) 3: 2-85, 2001.
4. <http://bim.ncrr.nih.gov/>
5. NIH data sharing policy at http://grants.nih.gov/grants/policy/data_sharing/
6. Clarke LP, Croft BY, Staab E, et al. National Cancer Institute initiative: Lung image database resource for imaging research. *Acad Radiol* 2001 May;8(5):447-50
7. <http://mirc.rsna.org/> and <http://rsna.org/mirc/>
8. E B. Suh, S Warach, H Cheung, et al.. A Web-Based Medical Image Archive System. *SPIE Medical Imaging Conference*, San Diego, CA. 2001.
9. ACRIN archived images access policy, <http://www.acrin.org/archivepolicy.html>
10. National Cancer Institute, Biomedical Imaging Program. Image archive workshop report (2000) at <http://cancer.gov/bip>
11. Staab E, Clarke LP, Baker H, Sullivan D. NCI image archive management workshop: a preliminary report. *Acad Radiol* 2001 Jul;8(7):690-1.
12. Perlyn CA, Marsh JL, Vannier MW, et al. The craniofacial anomalies archive at St. Louis Children's Hospital: 20 years of craniofacial imaging experience. *Plast Reconstr Surg*. 2001 Dec;108(7):1862-70.
13. Siegel E, Reiner B. Electronic teaching files: Seven-year experience using a commercial picture archiving and communication system. *J Digit Imaging* 2001 Jun;14(2 Suppl 1):125-7.
14. Williams BH, Mullick FG, Becker RL, Kyte RT, Noe A. A national treasure goes online: The Armed Forces Institute of Pathology. *MD Comput* 1998 Jul-Aug; 15(4):260-5.
15. DICOM website at <http://medical.nema.org/>
16. FDA Center for Drug Evaluation and Research's Electronic Regulatory Submissions and Review (ERSR) web page at <http://www.fda.gov/cder/regulatory/ersr/>

3D description of the human body shape: application of Karhunen-Loève expansion to the CAESAR database

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Abstract

In this Paper, the Karhunen-loève expansion is used for a compact 3D description of the human body shape. A set of eigenvectors is extracted from the CAESAR (Civilian American and European Surface Anthropometry Resource) database to define a basis for the human body shape space. Experimental results including the variation of the eigenvectors number with the size of the training set are presented.

Keywords: 3D Anthropometry, Karhunen-loève expansion

1. Introduction

The measurement of the human body (Anthropometry) is an essential part of the engineering design of cars, aircraft, workspaces, and clothing, to name a few. Traditionally such measurements involve the linear distances between anatomic landmarks and the circumference values at predefined locations. Practically, such measurements are limited to a set of about 100 values.

The main limitations of the traditional approach are the following:

- The set of values collected is so small that the only valid attempt to reconstruct the original shape is limited to very simple geometries.
- In most cases the set of unconnected (unregistered) values does not provide an accurate reconstruction of the original subject. Reconstruction ambiguities are due to the lack of a coordinate reference system.
- Surface shape is lost, and all attempts to reconstruct it from model-based approaches have yet to be validated.

A recently developed technology (Full body 3D digitizing [1]) allows increasing the number of measurements from a hundred to a million, and, in a small fraction of the time required by traditional measurement method. Furthermore each value in the data set is related to a common coordinate system, allowing an accurate and detailed 3D reconstruction.

The challenge now is to analyze the human body shape variability using statistical methods applied to a very large data set. This paper is proposing a method to achieve this goal. A number of methods have been proposed in the literature to represent 3D shapes. As an example, the wavelet transform allows multi-resolution description of 3D shapes [2]. However, the huge number of generated coefficients makes this tool far from

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providing a compact description. Superquadrics and hyperquadrics [3] have also been used for very compact description of 3D shapes but the complexity of the human body topology is too high for such a representation.

In the approach presented in this paper we consider the fact that the analysed 3D objects belongs to the same family. Intuitively we can think that the family is low dimensional. It follows that any member might be represented by a small number of parameters. The Karhunen-Loève expansion [4] is used to extract a small set of shapes, which allow the reconstruction of any of the shapes contained in the data set. The basic approach is similar to the one used in face recognition [5]. The data set here is three-dimensional data and the extracted shapes will be named "eigen-persons" equivalently to the "eigenfaces" obtained in face recognition experiments.

2.Method

2.1 CAESAR

The data used in this work has been collected within the CAESAR project (Civilian American and European Surface Anthropometry Resource) [6]. It is the first 3-D surface anthropometry survey performed in both U.S. and Europe. The CAESAR project is a collaborative effort with partners from several countries such as the Air Force Research Laboratory (AFRL) in Ohio, the Society of Automotive Engineers (SAE), the Netherlands Organization of the Applied Scientific Research (TNO) and the National Research Council of Canada (NRC).

During this project, body measurements have been taken for people between the ages of 18 and 65 in three countries: U.S, The Netherlands, and Italy. The most important data recorded are full body 3-D scans of people in three postures. Two scanners were employed, a Cyberware WB4 scanner in the United States and Italy, and a Vitronic scanner in The Netherlands.

2.2 Data pretreatment

For the purpose of this work we assume that the height of the human body is uncorrelated with its shape. In other words a short person and a tall person could have the same shape even though they don't have the same height.

Although within the traditional anthropometric studies, the human height is a measure that has been largely investigated, the description of the human shape is still a challenge. That is why in this work we eliminated the variability related to the height by normalizing the height of all the persons in the database.

Before the normalization though, it is important to align all the persons in order to have a common center of gravity. After alignment and normalization, the variability in the 3D data corresponds only to the variability of shape.

We adopted a voxel description of the 3D data. In this case a cube of 1m of dimensions has been sampled to n voxels, where $n = (200)^3$. A function describing the occupancy of those voxels is equal to one if the voxel contains at least one point, and zero otherwise.

2.3. Karhunen-Loève expansion

We consider the use of the Karhunen-Loève expansion, also known as Principal Component Analysis (PCA) [7] on the 3D data. The main idea of the approach is to find vectors which best account for the distribution of the body shape within the entire shape space.

Each 3D person is converted into a vector form $\bar{\Psi}_i$ describing the occupancy of the n voxels. The mean person over a set of N persons is given by:

$$\bar{\Psi} = \frac{1}{N} \sum_{i=1}^N \bar{\Psi}_i \quad (2.1)$$

Deviation vectors $\bar{\Phi}_i$ are generated (Equation 2.2) and arranged in a data set matrix A (Equation 2.3).

$$\bar{\Phi}_i = \bar{\Psi}_i - \bar{\Psi} \quad (2.2)$$

$$A = [\bar{\Phi}_1 \bar{\Phi}_2 \dots \bar{\Phi}_N] \quad (2.3)$$

The eigenvectors of the covariance matrix C form the orthonormal basis that optimally spans the subspace of the human shape.

$$C = A^T A \quad (2.4)$$

The eigenvectors, and their corresponding eigenvalues, of this $n \times n$ symmetric matrix C are ranked such that $(\lambda_i > \lambda_j)$ for $(i < j)$.

The magnitude of λ_j is equal to the variance in the data set spanned by its corresponding eigenvector \bar{u}_j as shown in Equation 2.5.

$$\lambda_j = \sigma_j^2 = \frac{1}{N} \sum_{i=1}^N \bar{\Phi}_i \cdot \bar{u}_j \quad (2.5)$$

It then follows that any vector $\bar{\Phi}_i$ in the data set, A , can be optimally approximated as shown in Equation 2.6. Thus, the n -dimensional body shape deviation vector can be re-defined as a linear combination of eigenvectors determined by M coefficients denoted by c_{ij} (computed using Equation 2.7).

$$\bar{\Phi}_i \approx \sum_{j=1}^M c_{ij} \bar{u}_j \quad 0 \leq M \leq n \quad (2.6)$$

$$c_{ij} = \bar{\Phi}_i \cdot \bar{u}_j \quad (2.7)$$

Computing the $(n = 200^3)$ eigenvectors and eigenvalues of C is however impractical. Determining the eigenvectors \bar{u}_i and eigenvalues λ_i of the $N \times N$ matrix given by Equation 2.8 represents a computationally feasible alternative to resolve the problem.

$$C' = A A^T \quad (2.8)$$

In fact, since the number of persons is less than the number of voxels $(N < n)$, there will be only N meaningful eigenvectors rather than n . Moreover, the first N eigenvalues and eigenvectors of C are directly computed as given by Equations 2.9 and 2.10.

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$$\lambda_i = \lambda'_i, \forall i \in [0, N-1] \quad (2.9)$$

$$\bar{u}_i = \frac{1}{\sqrt{\lambda_i}} \bar{u}'_i, \forall i \in [0, N-1] \quad (2.10)$$

The quality of the reconstruction is dependant on the fraction of the total variance contained in the M eigenvectors used in the reconstruction. This fraction is given by the equation 2.11

$$q_M = \sum_{i=1}^M \lambda_i / \sum_{i=1}^N \lambda_i \quad (2.11)$$

Thus each 3-D body scan will be characterized by a set of M coefficients, which represent a compact and reliable description.

3. Results

3.1 Reconstruction of human body using a set of eigenpersons

We applied the above method on a subset of the CAESAR database. Three hundred scans of male subjects in the standing posture have been used to extract a set of eigenpersons. The experimental results show that 185 eigenpersons span a space representing 80% of the variability induced by the training set. The first 5 eigenpersons are shown in the figure1. Only voxels corresponding to positive values are visualized.

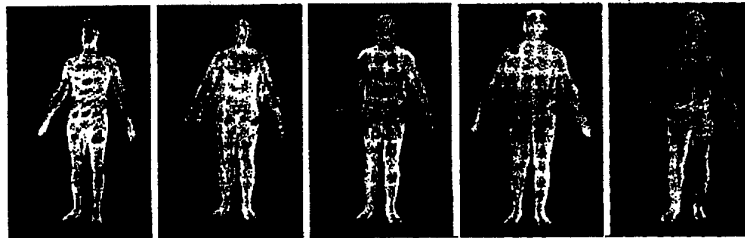


Figure 1. The first 5 eigenpersons. The visualized points correspond to voxels having positive values.

Figure 2 illustrates the original scans of two subjects included in the training set (2a and 2d), their corresponding sampled data (2b and 2e) and their reconstructed shapes (2c and 2f). Note the precise reconstruction of those two scans.

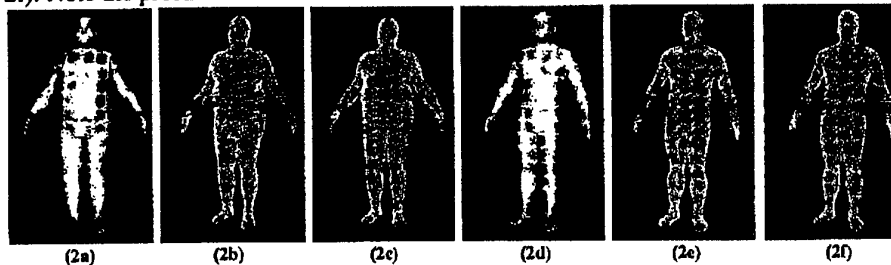


Figure 2. Original scans of subjects included in the training set (2a and 2d), corresponding sampled data (2b and 2e) and reconstructed shapes (2c and 2f).

The reconstruction of the subject illustrated in figure 3a is less precise using only 185 eigenpersons. We notice though the improvement (figure 3.c) using 260 eigenpersons. The fraction of variability spanned by those eigenpersons is 95% of the total variability.

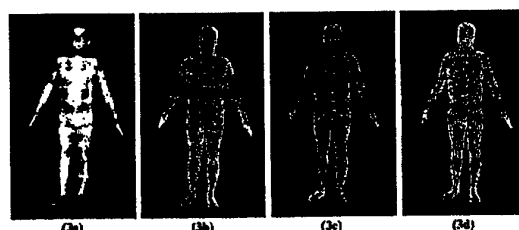


Figure 3. Reconstruction of a subject included in the training set using different numbers of eigenpersons. Original scan (3a), sampled data (3b), reconstruction with 185 eigenpersons (3c) and reconstruction with 260 eigenpersons (3d).

The reconstruction of the two persons non-included in the training set (figure 4c, 4f) is quite precise. The reconstruction could be improved with an appropriate choice of the training set.

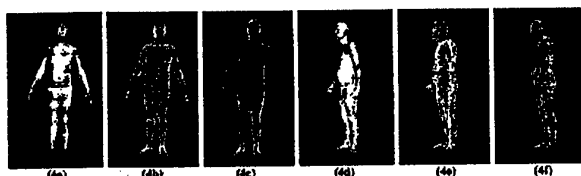


Figure 4. Original scans of 2 subjects non-included in the training set (4a and 4d), corresponding sampled data (4b and 4e) and reconstructed shapes (4c and 4f).

3.2 Variation of the eigenpersons number with the size of the training set

The proposed approach was applied to different embedded sets of human body scans in order to study the variation of the number of the eigenpersons required to span 80% of the variability induced by the training set.

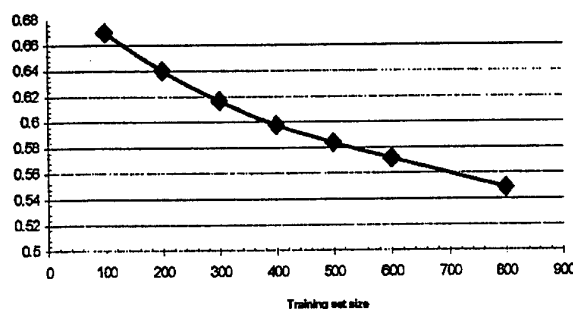


Figure 5 Variation of the ratio of the eigenpersons number needed to span 80% of the variability and the size of the training set

The decrease of the ratio of the eigenpersons number and the size of the training set (figure 5) prove that the increase of the eigenpersons number will be insignificant from a certain training set size. Which mean that we can extract from this training set a group of eigenpersons that can span a wide variability in the entire human body shape space.

During this preliminary study, the 3-D scans used represent a reduced number of polygons(20000). We expect that using models of full resolution(300000 polygons) will reduce the number of the required eigenpersons and so enhance the compactness of the developed description of the human body.

4. Applications

One of the applications of the proposed method is in the understanding of the human shape variability and its distribution for a given population in the design of products such as seats, workstations and clothing. In clothing applications for example, a better understanding of the human shape variability should lead to an improved sizing strategy reducing inventory and unsold items. In computer simulation for the design of automobiles, the method should allow the validation of human models and help in the selection of cases representative of the target population to which such car models are designed.

5. Conclusion

This paper presented an approach to describe the human body shape which allows 3D reconstruction for visual evaluation of human models, either real or computer generated. It also gives a new tool for the statistical analysis of 3D anthropometric data such as the ones collected in the CAESAR project. This preliminary study shows that the representation is compact since a 3D model of human body containing thousands of polygons could be characterized by a few hundred coefficients.

References

1. K..M. Robinette, M.W. Vannier, M. Rioux, and P.R.M. Jones, 3-D Surface Anthropometry : Review of Technologies (L'Anthropométrie de surface en trois dimensions: examen des technologies). Neuilly-sur-Seine: North Atlantic Treaty Organization Advisory Group for Aerospace Research & Development, Aerospace Medical Panel, 1997.
2. S.Muraki. Volume Data and Wavelet Transforms. IEEE Computer Graphics and Applications, pp.50-56, 1993.
3. M.Ohuchi, T.Saito. Three-dimensional shape modeling with extended hyperquadrics.
4. Third International Conference on 3-D Digital Imaging and Modeling, pp 262-269, 2001.
5. K.Fukunaga, Introduction to Statistical Pattern Recognition. NY Academic, 1972.
6. M.Kirby, L.Sirovich. Application of the Karhunen-Loève Procedure for the Characterisation of Human Faces. IEEE Transactions on Pattern Analysis and Machine Intelligence, (1): 103-108, 1990.
7. K. M. Robinette, H.Daanen, E.Paquet The Caesar Project: A 3-D Surface Anthropometry Survey. Second International Conference on 3-D Digital Imaging and Modeling, pp. 380-386,1999.
8. L.Lebart, A. Morineau, M.Piron. Statistique exploratoire multidimensionnelle. Dunod 1995.

Recent advances in Korean anthropometry

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Abstract

Anthropometry deals with the measurement of human body by 2D data and certain other physical characteristics of the human body by 3D data such as volumes, proportions, body contours and body silhouette. Here we would like to introduce part of what has been done in Korea, concerning anthropometric surveys and their applications to provide informations for products design.

Keywords: Anthropometry, products, design, body

1. Introduction

It has become generally recognized that both workplaces and products which are related to the human body, must be designed with reference to body measurements and the range of movement of the people concerned in mind. In the new trend of globalization, one may think that all humans may one day finally not be very different from each other, eating other country dishes, dressing more or less all in the same manner, behaving along a more unified way of thinking. This is already true to a certain extent, and the trend with several pauses and reactional short periods, will probably continue. But, interestingly one of the most important element of globalization (beside profit), the ever widespreading of information all over the world, seems to contain in itself the necessity of taking more and more in account the characteristic of individuals. Indeed, the technological information age means also that every producer and market researcher looks more and more towards any information he can get about his customers (behavior, society, cultural and physical features), to try to maximize his market. He may try to do without, but then may risk much, for others will probably not do so. Another aspect of the dissemination of information and knowledge is also that consumers all over the world become at the same time more educated and will no doubt be more and more choosy. The average individual will probably not be too dissatisfied to have more or less an average product, as long as it fits well its desire and also his physical features. In one word, products will have to suit much more individuals. In the field of clothing as in many others, advertisement will have to be paired increasingly with quality and suitably and rely somewhat less on consumer psychology. Individuals, even those who follow fashion trends, will give their preference to those producers who can produce garments which suit most their physical features. The importance of good physical statistics, by countries, ages, sexes and in multiracial societies, races or interracial types must be then emphasized. Indeed such statistics allow to define some virtual individual average shape for each classes, to recognize the growing importance of them and changes occurring with the passing of time. Here we would like to introduce part of what has been done in Korea, concerning anthropometric surveys and anthropometric applications.

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2. Methods

2.1 Korean national survey

The first national anthropometry survey in Korea was conducted in 1979 by the Korean government division, the National Institute of Technology and Quality. It collected at the time, data concerning 17,000 samples residing in various parts of the country from the age of six to fifty. A number of 117 measurement dimensions were taken, using calipers and tape measure. Thanks to these data, the NITQ established 46 items defining Korean standards concerning clothes, furniture, desk and chairs. 41 of them (KS0035 to KS0096) concerned the size designations of men's wear, women's wear, brassieres and socks. After this survey, the Korean government presented a national anthropometric survey every 5 or 6 years. In 1997, the 4th rather large-scale anthropometric survey was carried out throughout the country and samples were selected more randomly to get better representative anthropometric data. Surveys showed how much Korean individual's physical features had changed during these last 10 years: with economic development and better health facilities, height, body proportion and even face shapes had evolved and were still changing. A new need for re-examination of some Korean standards was again acknowledged, specially those relating to body size: clothes, shoes, headgear and the like. Thus, 1998 has been thus the year of data analysis research conducted for the definition of a new body size classification updating the garment sizing system for Koreans, the year 1999 concerned with the standardization of shoe sizing system, and the year 2000 concerned with the headgear sizing and the table sizing. The 5th survey will be performed in 2003 using 2D and 3D method. The basic informations for the Korean national surveys are shown in Table 1.

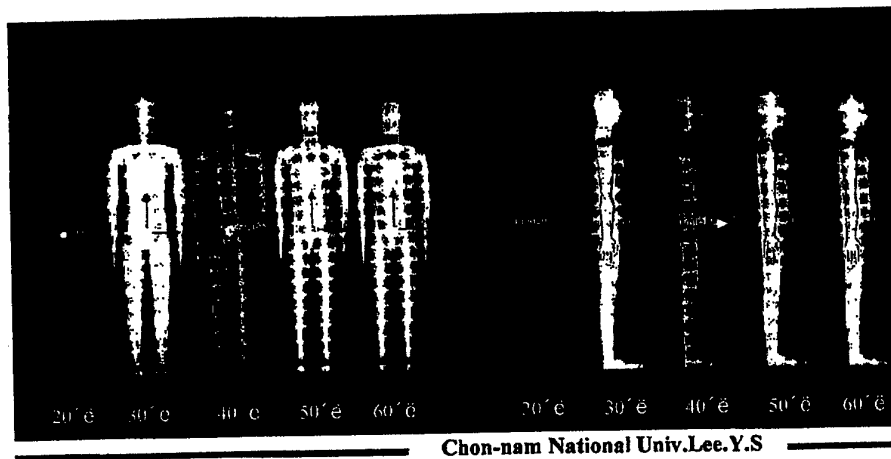
	1 st survey	2 nd survey	3 rd survey	4 th survey	5 th survey
Year	1979	1986	1992	1997	2003
Age	6-50yrs	6-50yrs	6-50yrs	1-70yrs	1-0yrs
Samples	17.000	21.650	8.800	13.000	20.000
Dimension	117	80	84	120	200
Method	2D	2D	2D	2D	2D+3D
Application	Establish 46 korean standard (KS K 0031 etc)	Updated 41 Korean standard (KS K 0034 etc)	Updated 44 Korean standard (KS G 2016 etc)	Updated Korean standard (KS K 0051, KS G 3405 etc)	

Table 1. Korean national surveys

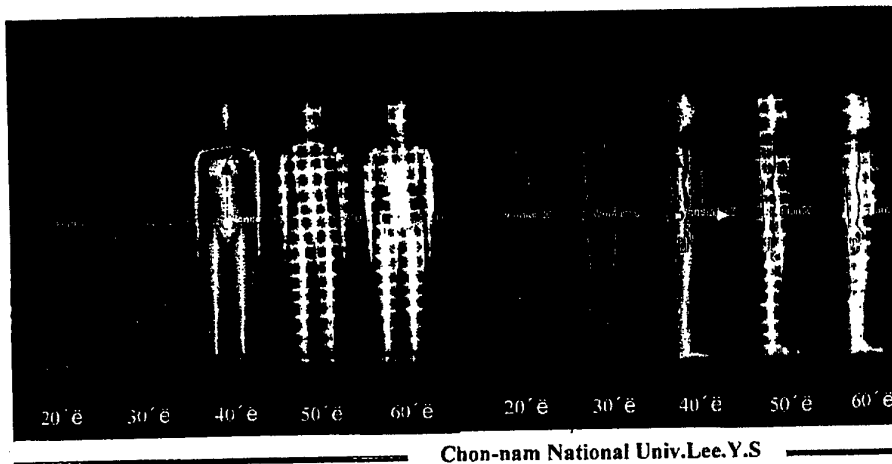
2.2 Human modelling by age

With the data which were obtained from national survey, we compared the body shape by age. Figure 1 and 2 show the comparison of the body shape between different age groups. We found that there were few significant differences in body depth between young and middle age groups. All these differences need to be reflected to design products.

Human Modeling (Korean Man)



Human Modeling (Korean woman)



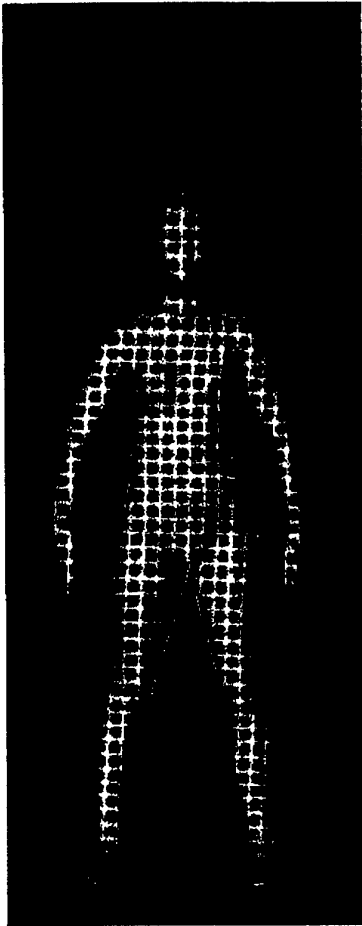


Figure 4 3D scan data

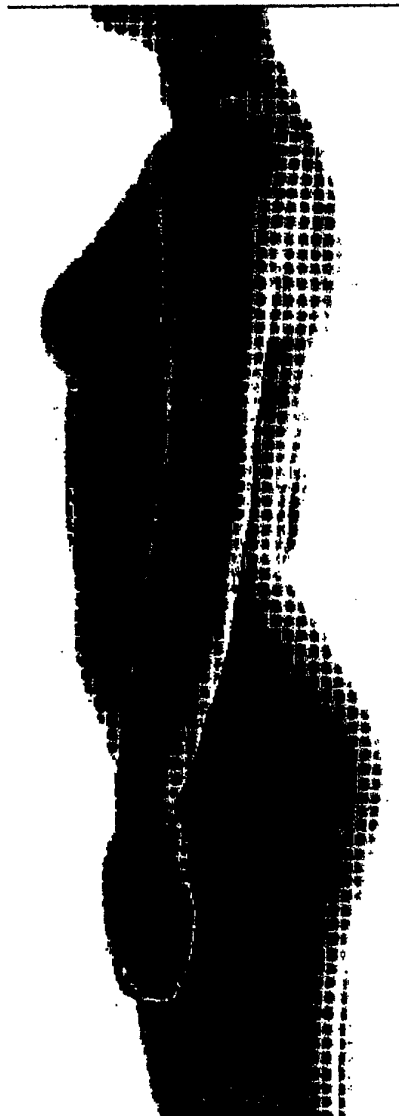


Figure 5 Body silhouette in woman

Automatic shape modeling of the foot: towards a database of foot shapes

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Abstract

Homologous human shape modeling is critical to utilize 3D human body data for product design. Software libraries for homologous modeling were developed and application software to model the foot form was also developed using the libraries. This software was incorporated into a compact low-cost foot scanner. With the scanning system, retailers can select/recommend well-fitting shoes to customers. By storing a copy of scanned data that does not contradict with the privacy of customers, customers can enjoy browsing their foot shape data or shopping in electronic commerce. This system is useful to make a large database of foot forms. Possible problems in making a large database in this manner are discussed.

Keywords: Anthropometry, human body shape, foot

1. Introduction

With 3D body scanners, a large database on body dimensions and forms can be developed efficiently. It is difficult, however, to utilize the information on the 3D human body forms for the product design only with millions of surface data points and dozens of anatomical landmarks. Millions data points are verbose to describe a body form, and they have no anatomical correspondence. Landmarks have anatomical correspondence, but they are too few to represent the surface form. Thus, shape representation methods using hundreds to thousands data points with anatomical correspondence have been proposed. Such methods are called "normalized modeling" [1] or "homologous shape modeling" [2]. The modeling protocol is not unique, but the modeling guideline is defined reasonably based on anatomical correspondence and application purposes of the models.

In this paper, the common and basic protocols for the homologous modeling are mentioned, and development of a foot scanning system with an automatic shape modeling software is mentioned. Finally, a method is proposed for collecting a large amount of foot shape data using the foot scanning systems installed in shoe retailers.

2. Homologous shape modeling

2.1 Basic modules designed for homologous shape modeling

We have developed several homologous shape models for different body parts. Fig. 1(a) shows a torso model for developing a dressmaking dummy [3]. It consists of 547 data points (1039 polygons) defined based on 25 landmarks. Fig. 1(b) is a face model for designing a spectacle frame, which consists of 211 data points (366 polygons) based on 61 anatomical landmarks [4]. A foot model for shoe last design is shown in Fig. 1(c). This model has 295 data points (586 polygons) defined based on 9 landmarks [2]. Common and basic protocols for the geometrical processing to generate homologous models are as follows:

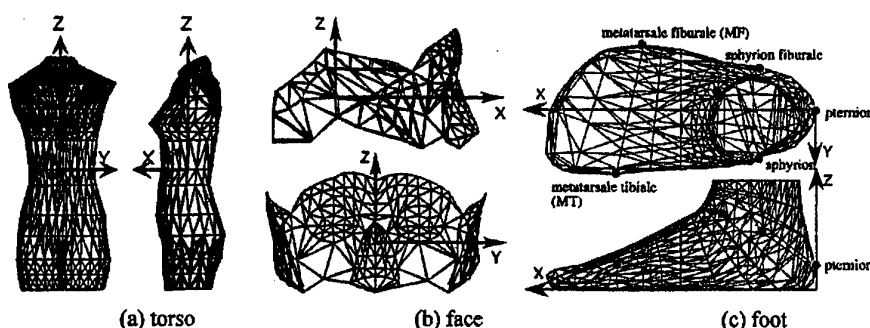


Fig. 1: Homologous shape modeling.

- A. Generation of an interpolated point: calculate equidistant dividing points of a shortest surface distance between two landmarks.
- B. Generation of a cross section
 - (b-1) The cross section is defined by three landmarks.
 - (b-2) The cross section is perpendicular to the coordinate plane and contains two landmarks.
 - (b-3) The cross section is parallel to the coordinate plane and contains one landmark.
- C. Generation of dividing points on a cross section
 - (c-1) The center of the cross section is defined as the centroid or a uniquely defined point such as the midpoint of two landmarks. The contour of the cross section is divided into segments by the same angular interval. The starting point on the contour is defined by the axis of coordinates.
 - (c-2) The contour of the cross section is divided into segments by the same distance interval of contour line instead of the same angular interval.
 - (c-3) The whole contour of the cross section is divided into segments by the lines connecting the center of the cross section and landmarks projected on the plane. The center of the cross section is defined as stated in (c-1). Each segment contour is divided according to the process (c-1) or (c-2).

2.2 Foot shape modeling software "Di+"

Software libraries for generating interpolated points, cross sections and dividing points were developed to do the basic geometrical processing. Application software "Di+" to

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generate a homologous foot model was developed using the software libraries. The software was coded by I-Ware Laboratory Co, Ltd.

3. Application of homologous shape models

3.1 Representation of shape difference

When two body forms were represented by homologous shape models, the difference between two forms can be represented by the spatial distortion of the control lattice points (Fig. 2). This is the Free Form Deformation (FFD) technique [5]. With the original FFD technique, a 3D shape is deformed smoothly by moving the control lattice points. When two body forms were represented by homologous shape models, the optimal distortion of the FFD grids can be calculated to minimize the sum of Euclidian distances between corresponding vertices. Application software "Darcii-T: Digital and Anatomical shape Representation with Control-points for Inter Individual Transformation" have been developed for this purpose. With Darcii-T, the optimal distortion of the FFD grid to deform the original model into the target model can be calculated, and the distortion function can be applied to any objects [2].

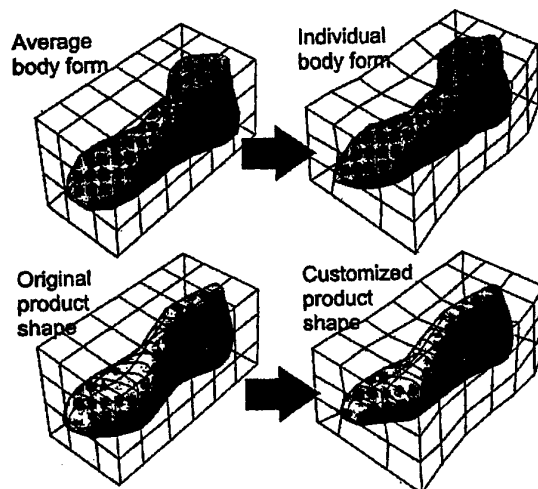


Fig. 2: Last design using the deformation based on the FFD grid.

3.2 Designing a well-fitting shoe last

The average form can be calculated easily for homologous models. An average foot form is calculated for the panels for whom the same existing shoe fits well. The average foot form and the last shape for the shoe is the master pair with good fitting comfort. The shoe does not always fit to a customer even if his/her foot length is the same with the panels because of the foot shape differences. Thus, the customer's foot is modelled by Di+ and the difference between the average foot form and the customer's foot form is represented as the FFD grid distortion by Darcii-T (Fig. 2, top). The distorted FFD grid has the information on the differences in the foot size and shape. Then the distorted FFD grid is applied to the last shape for the existing shoe, and a new last shape for the customer is

calculated (Fig. 2, bottom). The digital last can be materialized by an NC lathe, and a shoe manufactured using the last.

4. Foot database by foot scanning systems in retail shops

4.1 Foot scanning system "INFOOT"

A foot scanning system "INFOOT" has been developed with I-Ware Laboratory Co. Ltd (Fig. 3(a)). This system consists of a compact and low-cost foot scanner, automatic foot modeling software (Di+), and FFD software (Darcii-T). Eight cameras and four laser line projectors were installed in the scanner. Using a glass plate for the standing plane, complete shape including the sole can be measured. The accuracy and the resolution of this scanner was 1.0 mm [6].

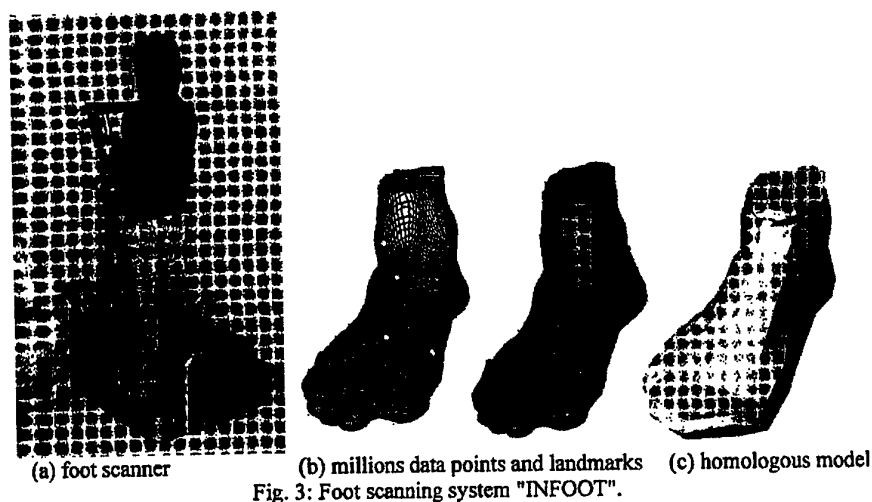


Fig. 3: Foot scanning system "INFOOT".

Special marker seals are pasted on the following 5 landmarks: (1) Metatarsale tibiale (MT), (2) Metatarsale fibulare (MF), (3) Sphyrion fibulare: the tip of the lateral malleolus, (4) Sphyrion: the tip of the medial malleolus, (5) the lateral junction point; a point at the junction between the leg and foot on the lateral aspect of the dorsum pedis. It is defined as the crossing point of the tendon of M. extensor digitorum longus leading to the 5th toe and the crease which appears when the subject flexes his/her knees and ankles. Then the foot is scanned in 10 sec. Above mentioned 5 landmarks are detected and labeled automatically. Four more landmarks are detected automatically based on the curvature of the foot surface. Seventeen foot dimensions are calculated from the scanned data and landmarks in 5 more sec. Millions data points and 9 landmark coordinates are saved (Fig. 3 (b)). Consequently, the homologous foot model (Fig. 3(c)) can be calculated automatically.

Table 1 compares foot dimensions calculated by the scanner and measured by an expert using the traditional method. The difference was significant for all dimensions, but the MAD (mean absolute difference) was within 1.0 mm for most of them. Repeatability of measurements obtained by the scanner is as good as that for the manual measurements.

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This system is purchasable from I-Ware Laboratory Co, Ltd., and over 20 systems have been installed in shoe retailers and manufactures in Japan, Korea, US, and Germany.

Table 1: Difference between the traditional method and INFOOT (unit: mm)

*, $p < 0.05$, **, $p < 0.01$, ns: not significant.

		Mean by INFOOT	Mean by trad. method.	Difference	paired t-test	Correlation coefficient
2	Ball girth	242.0	240.3	-1.7	**	0.988
1	Foot length	241.9	243.1	1.1	**	0.997
10	Instep length	177.3	176.9	-0.4	ns	0.989
11	Fibular instep l.	158.3	155.5	2.8	**	0.991
3	Foot breadth	99.9	99.8	-0.1	ns	0.992
7	Heel breadth	64.0	63.6	0.5	**	0.996

4.2 A large foot database

An important feature of INFOOT system is automatic generation of a homologous foot model. Another feature is information services related to human body forms. These information services are based on our original technologies and put into practice by I-Ware Laboratory Co, Ltd (patent pending).

Usually, foot data measured by a scanner located in a shop belongs to the shop. Our proposal is that measured data should be accessible from the customer him/herself. Personal information including name and address must be managed by the shop, and copy of information which does not violate the privacy is sent to the common database server with the customer's agreement. Sent information is ID number, birth year, measured date, stature and foot data. If a customer has measured his/her foot by this system before, the customer can present his/her ID number to a clerk of a shop. The clerk can download the customer's foot data from the database server, and utilize it to select or recommend well-fitting shoes to the customer. In electronic commerce, consumers select the brand/design from a shoes catalogue and specify their ID number for the foot data. Consequently, the consumer would get well-fitting shoes. A free viewer of 3D foot data has been distributed from I-Ware Laboratory web site (<http://www.i-ware.co.jp/>). Consumers can download their foot data and the viewer, and enjoy browsing 3D foot data on a PC.

4.3 Advantages

This idea for creating foot database is different from the traditional anthropometric surveys. A large amount of data is gathered by ubiquitous foot scanners used in the business for selecting or manufacturing well-fitting shoes. These data must be handled with the agreement of every customer. With this strategy, a large foot database would be created with a small project budget. The information service business does not started yet, but data for over 700 feet are stored in the database during a trial service of 6 months.

It is a very important and useful feature of INFOOT system to store the foot data with homologous shape models. With homologous models, it is possible (1) to obtain the shape distribution map, (2) to calculate the average form, and (3) to generate standard deviation forms on the distribution map.

4.4 Known problems

There are two problems for this database strategy. One is the quality control and the other is the biased sampling. Quality management of the measurement equipment is not so difficult, whereas the quality management of the measurement protocol is difficult. We should control the quality of measurers in landmarking and instruction to subjects. With a proper protocol, a measurer should instruct to a subject "Stand naturally and look straight ahead. Distribute your weight equally on your left and right feet." For controlling the subject's gaze, INFOOT system displays the measured shape on the screen on real time. The subject watches the screen naturally, thus their posture becomes stable. For controlling the subject's weight balance, we plan to install a weight sensor to the footstep of INFOOT system. It is very difficult to control the quality in landmarking. We are developing a new method to reduce the number of landmarks to be located by the measurer. In the present system, 5 anatomical landmarks must be identified by a measurer. Using the new method, only MT and MF are needed to be identified.

Handling the biased sampling is also difficult. Females, younger subjects, and subjects in higher social classes would be over represented, when we use the proposed system. We can get the location of the measurement equipment, gender and the age of subjects, but cannot get any information on the birthplace, ethnic group, social class, education level, or occupation. To complement under represented strata, a measurement project by public organization may be efficient, and it need not be a big project.

5. Conclusion

With homologous models, average form and the standard deviation forms can be easily calculated. Software libraries for homologous modeling were developed and application software to model the foot form was also developed using the libraries. This software was incorporated into a compact and low-cost foot scanner, and the scanning systems have been installed in some shoe retailers. With the scanning system, retailers can select well-fitting shoes for customers, and customers can enjoy browsing their foot shape data or shopping in electronic commerce. A large database can be constructed by using this system with special care for quality control and biased sampling.

References

1. M. Bayley, "The Use of 3D Body Normalisation to Enable Powerful Data Analysis Technique," *Scanning 3D - Human Modeling*, Paris, 2001.
2. M. Mochimaru, M. Kouchi, and M. Dohi, "Analysis of 3D human foot forms using the FFD method and its application in grading shoe last," *Ergonomics*, Vol. 43, pp. 1301-1313, 2000.
3. M. Kouchi and M. Mochimaru, "Development of a new dressmaking dummy based on a 3d human model," *Scanning 3D - Human Modeling*, Paris, 2001.
4. M. Kouchi and M. Mochimaru, "Analysis of 3D Human Face Forms and Spectacle Frames Based on Average Forms," *SAE Digital Human Modeling for Design and Engineering*, Munich, 2002.
5. T. W. Sederberg, "Free-From Deformation of Solid Geometric Models," *ACM SIGGRAPH'86 in Computers & Graphics*, Vol.20, pp. 151-160, 1986.
6. M. Mochimaru and M. Kouchi, "Development of a low cost foot scanner for custom shoes by the FFD," *Scanning 3D - Numerisation 3D*, Paris, 2001.

A Web3D based CAESAR viewer

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Abstract

The CAESAR (Civilian American and European Surface Anthropometry Resource) project completed in 2002 has collected 3D scans of over 5000 subjects. We have created a 3D interface, the NIST CAESAR Viewer (NCV), utilizing the Virtual Reality Modeling Language (VRML) to provide 3D access via the Web. In addition to simply viewing the 3D scans we have augmented the display of the body with interactive anthropometric landmarks and contour line displays. The landmarks and viewpoints associated with the landmarks are automatically placed onto the body as a visual anthropometric glossary. Display of the contours boundaries are adjusted by the user moving sagittal, coronal and transverse cutting planes. This paper describes the functionality of the evolving NCV viewer.

Keywords: VRML, Web3D, anthropometry

1. Introduction

The NIST CAESAR Viewer (NCV) enables users to view and manipulate the display of CAESAR 3D body scans. NCV is a work in progress and several versions of the interface exist with varying functionality. The key advantage of NCV is that users, with appropriate access to the CAESAR database of bodies, can view the surface scans on inexpensive PCs or any computing platform with a VRML [1] browser. Anthropometric landmarks are easily visualized by showing the landmark locations on the body. It is a natural extension to create 3D illustrations of the landmarks by placing them on 3D computer generated bodies. Figure 1 illustrates the display of a single body with landmarks and contours. In addition to simple displays of the bodies, users can view multiple bodies and the data associated with the anthropometric landmarks. The user can toggle the display of landmarks, contour lines or the body surface as desired.

The NCV provides the anthropometry standards community a way of producing 3D illustrations for data visualization, and facilitates communication among members. In addition creation of a 3D anthropometric glossary allows non-professionals a simple way of introducing anthropometric concepts. As the NCV becomes more robust we intend on using it as a low-cost tool for anthropometric measurements and analysis of 3D scans.

DISCLAIMER: Mention of trade names does not imply endorsement by NIST.

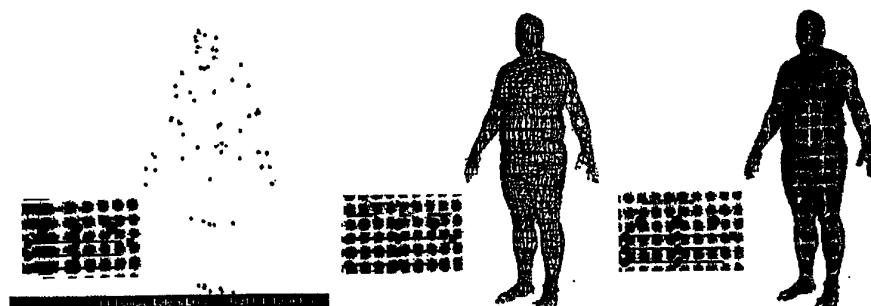


Fig 1. : Body with landmarks, contours and surfaces toggled on.

2. System evolution and background

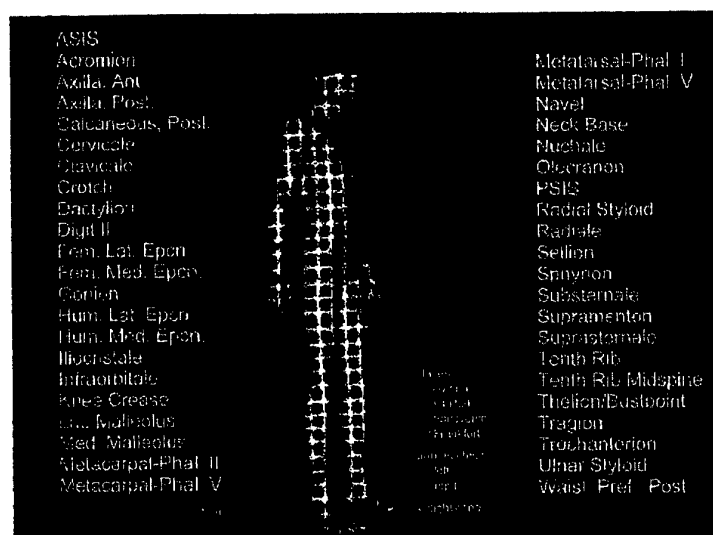


Fig 2. : AnthroGloss screen layout with Frankfort plane and sight cone indicators turned on.

Before our direct involvement in the use of CAESAR body scans we created a system called "AnthroGloss" [2] shown in Figure 2, which uses a synthetically created body. We placed anthropometric landmark spheres on the body by hand, a laborious process. In AnthroGloss users select a sphere causing a change in the viewpoint and the name of the selected landmark appears in a large size font in the middle of the display. The list of landmarks can be repositioned by dragging the entire column of names. Reference planes can be toggled on and off via the control panel. The glossary system also allows users to toggle on or off a variety of display indicators. These include the Frankfort plane, and a sagittal, coronal and transverse cutting planes. The planes were derived from illustrations in *Anthropometric Methods* [3]. Arm reach volumes, partial spherical areas, can also be displayed. The areas for the arm reaches were based on standard illustrations [4,5]. Also,

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the user can select from among several types of landmark nomenclatures. Currently the SAE G13 Human Modeling Technology Committee is working on a comprehensive anthropometric landmark dictionary, spearheaded by John Roebuck. Roebuck was kind enough to supply an early version of this dictionary and we have included this version of the SAE AIR 5408 [6] names in our latest version of the visual glossary.

3. Display interactions in NCV

The NCV system uses landmark coordinates from the CAESAR data set to automatically place the landmark spheres on the surface of the scans. Each sphere is made interactive. This was implemented by using VRML TouchSensors so that the landmark data pops up when the user places the cursor over the landmark spheres. We automatically generate points of view, using VRML Viewpoint Nodes, associated with each landmark to allow the user to get close-up views of the landmarks in context of the body. We generate the viewpoints by surrounding the body with an enclosing cylinder and drawing a vector from the landmark to the cylinder. The intersection point between the vector and the cylinder becomes the viewpoint for that landmark. The end result is a system that automatically generates views of the landmark spheres, places them on the body and automatically generates associated viewpoints for each landmark. These interactive bodies are the equivalent of our previous "AnthroGloss" body however they are now generated automatically for each CAESAR body rather than manually constructed for a particular synthetic body.

Figure 3 illustrates the most complex version of the system. This version includes the ability to toggle on or off body textures, landmarks, and contours. It also provides the ability to select a color for the entire body. Labels for the control slider change as appropriate to match the particular functionality selected.

The controls currently available to the user allow for the display of multiple (up to 10) bodies. The control panel operates on the "current" body indicated by a box surrounding the body. The "current" body is selected by simply clicking the body. Contour lines associated with sagittal, coronal and transverse cutting planes can be displayed. When the user selects a cutting plane an animated display of the contour cut plane is created and the user can drag the cutting plane through the body watching the effect on the contour. Finally the user can measure distances on the contour display by selecting start and end points on the contour lines. The distances are in the same units as the original CAESAR data.



Fig. 3: Textured body display with multiple bodies and contours.

4. Issues, problems and future work

Currently there are only three widely used VRML browsers, CosmoPlayer (www.sgi.com/software/cosmo/player.html), Contact (www.blaxxun.com) and Cortona (www.parallelgraphics.com). CosmoPlayer is a discontinued product, for PCs, and is no longer maintained, however it is supported by SGI for their IRIX workstations. Contact and Cortona are both being actively developed and expanded. It is often a challenge to create VRML content that plays satisfactorily in multiple browsers. The NCV display generally does play back correctly but does on occasion exhibit idiosyncrasies due to the different behavior of the browsers. It may be more effective to use a proprietary Web3D technology such as Viewpoint (www.viewpoint.com) or Shockwave 3D (www.macromedia.com), as these are both available on a number of common platforms and may provide superior displays and download times via geometric compression.

We have also begun to examine the advantages of using a large format wall size 3D display. True 3D is achieved by the use of LCD shutter glasses and the image is projected life size. We use a pair of FakeSpace Rave [7] walls arranged in a corner configuration. The life-size nature of the display gives the user an intuitive perception the physical size of the human who was scanned. Standing in front of a 3D life-size gives one a powerful sense of presence and a clear sense of the size and distances of the data. Interaction with data in this 3D space remains problematic. However we expect to tackle that issue in the future through the use of new input devices.

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We also intend on integrating this type of visualization with a set of children's anthropometric data we have made available on the "AnthroKids" web site. AnthroKids [8] data is based on the only comprehensive anthropometric survey of children ever conducted in the USA [9] and remains a valuable resource. Visualization of children's anthropometry should prove useful for a variety of design issues.

We expect to make the NCV available to the general public for free and intend on making it a valuable resource for both people using CAESAR data and other 3D body scans. The proliferation of inexpensive high quality computer graphics hardware will make NCV more useful as time goes on.

Acknowledgements

The VRML versions of the CAESAR bodies (geometry only) were created by Eric Paquett of the NRC. Thanks to Kathleen Robinette (of CARD Lab and CAESAR project leader) for feedback on NCV and explaining the CAESAR project, and John Roebuck (of Roebuck Research & Consulting) for providing invaluable advice on anthropometry.

References

1. ISO/IEC, "The Virtual Reality Modeling Language," International Standard ISO/IEC 14772-1:1997.
2. Sandy Ressler, "A Web-based 3D Glossary for Anthropometric Landmarks," Proceedings of HCI International 2001, New Orleans, LA, August 5-10, 2001.
3. Roebuck Jr., J. A. "Anthropometric Methods: Designing to Fit the Human Body," Human Factors and Ergonomics Society, 1993.
4. Dreyfuss H. Associates. "The Measure of Man and Woman," Whitney Library of Design, 1993.
5. Woodson, W.E., Tillman, B., Tillman, P. "Human Factors Design Handbook second edition," McGraw Hill, 1992.
6. Roebuck Jr., J. A. "DRAFT 6 of Sample Visual Index Illustrations for AIR 5408 Dictionary of Anthropometric Landmarks, Lines and Planes for Computer Human Modeling," SAE G13, 2001.
7. Fakespace Systems Inc, <http://www.fakespacesystems.com/workspace1.htm>
8. NIST, AnthroKids - Anthropometric Data of Children, ovrt.nist.gov/projects/anthrokids
9. Snyder, R.G., Schneider, L. W., Owings, C. L., Reynolds, H. M., Golomb, D. H., Schork, M. A., "Anthropometry of Infants, Children, and Youths to Age 18 for Product Safety Design," University of Michigan Ann Arbor, UM-HSRI-77-17, 1977.

Some tools for understanding anthropometry

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Abstract

Two decades of experiences in education in engineering anthropometry to students in Industrial Design Engineering and to Industries resulted in useful guidelines for the developing of 3D-tools.

Keywords: 3D-anthropometry, education, tools

1. Introduction

During the 2 last decades we experienced several ways of learning students and companies about anthropometry.

First thoughts were that learning some knowledge about the normal distribution and percentiles would help especially if as an example a list with the values of mean, sd, p5 and p95 about Flying Personnel 1954 was given.

But you can't go on with designing everything in Holland for American Pilots. We were happy with the publication of the German Din 33402. But after a while we compared the stature (with the body weight the only available anthropometry at that time in Holland at the beginning of the eighties) young adults of age 20 between German and the Netherlands. The conclusion was a higher value for the stature of 2% for all percentiles for females and 3,5 % for males of that age group. With that knowledge we created a educational standard for students called DINED, which meant to show we used the German DIN as well as Dutch data. In fact it was included in an a6-paper form in a small pocketbook called 'Kleine Ergonomische Datensammlung' [1], which was given for free to all students by the faculty. This student standard was meant to be used in the education of design engineering to learn about percentiles, correlation, adding and subtracting of measurements and to have a reasonable estimation of some variables for Dutch adults, children and elderly.

2. DINED

DINED was soon used as a standard in the Netherlands by the industry especially because it was attached to the Dutch Standard NEN1813 for office furniture and it was published in all kind of handbooks. Now after 17 years of using we can evaluate this simple tool.

We learned the following [2]:

-Percentiles were still just added despite of our efforts to include an algorithm about how to add or subtract two normal distributed measurements taking care of their correlation.

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- Because we published P5 and P95 after 5 years the users (designers and companies) didn't use any other percentiles; we called that the P5 syndrome.
- Because this DINED-table was more or less 1 dimensional, users were not triggered to think in 2 or 3 D.
- Because it was mainly presented as meant for adults of age 20-60, populations were not split or added in spite of our efforts to include an algorithm about this subject. For example if you are designing for a Dutch nursing home the population mostly consist of 75% female en 25 % male, which influences the anthropometry of the mixed group.
- The information about the secular trend was very popular and raised many comments and some improvements. This means a graph with a timeline is better then to mention just some figures.
- The information about variance, variation and correlation was to compact and should be illustrated
- Some variables were not popular: handwidth with thumb was included and people were asking for handwidth metacarpal; afterwards it was understandable.
- Some variables could easy be calculated like the vertical legroom from the sum of the popliteal height and the thigh clearance, but that was mostly not understood by students and mostly asked by industry.
- Calculations of percentiles can better be done graphically
- The user forgets the influence of the posture and the task
- The best lesson is that users always forget the influence of the correlation with the second and the third dimensions
- Also important for other teachers might be that we always saw ergonomics as one of the four discipline of the industrial design engineering. The other three are formgiving, innovation management and engineering. Anthropometry is seen as a very essential part of ergonomics. This means we include the knowledge of anthropometry in various stages of the process of product development.

3. AIS Anthropometric Information System

After our experiences with DINED we set up a digital system; first in DOS and later under Windows and currently a JAVA-applet is developed on <http://dutoh60.io.tudelft.nl>
In this design we want to overcome the lack of knowledge in anatomy by the users by showing pictures. We want to overcome the lack of knowledge of what we call the anthropometric design process by stimulate the user/designer to follow a stepwise process. For example they have to say something about the following points in a sequence:

- some demographic parameters of population where to design for
- a posture that will be used
- possible manual handling that will occur
- which are the relevant product or workplace dimensions
- which are in accordance the relevant human dimension
- what are the critical values
- what is the intercorrelation between the relevant dimensions
- what are the available anthropometrical sources
- what is needed to be estimated
- what are additional factors for clothing or posturing?

This means in most cases that the needed data are not complete and must be estimated. That is why we found in handbooks of Roebuck and Anthropometric Source Book and developed ourselves calculation methods to make better estimations for designers. These formulas are included in the AIS-software.

4. DINED digital

Because the development of AIS is slow we had in the meantime some experiences with a faster system and based on Flash-software. This can be seen at <http://www.io.tudelft.nl/research/ergonomics/build/>. In this site it was easier to enter several populations. In the near future we have to decide which development is the most adequate for the users as well for the software developers.

5. ELLIPSE

Another tool that came up to make the 2 dimensional anthropometrical world more understandable for designers was the experience with the first scatterplots or bivariate normal distribution we saw in literature [3]. These were very useful but time consuming. This was the reason why we made this phenomenon also interactive. An example of recent use of ELLIPSE can be seen on the last page of this paper. In that particular case the hip width was shown in relation to the chest width, because that were two relevant dimensions for that posture and the critical manual handling.

6. Recommendations

To develop new tools for anthropometry it would be recommended to involve future users during the development process on regular bases. Experiences from the past with 1D and 2D-data learn that 3D data not only should be available for education but also the tools to use these data in the design process.

References

1. Lange, W., *Kleine Ergonomische Datensammlung*, Verlag TUV Rheinland, Dortmund, 1981.
2. Molenbroek, J.F.M. and A.I.M. Voorbij, "Aanzet tot een nieuwe Nederlandse antropometrie tabel voor lichaamsmaten; de DINED revisited" *Tijdschrift voor Ergonomie*, 26,3,25-30,2001.
3. Sittig, J. en H. Freudenthal, *De Juiste Maat, lichaamsafmetingen van Nederlandse vrouwen als basis van een nieuw maatsysteem voor damesconfectiekleding*, Stafleu, Leiden, 1951.

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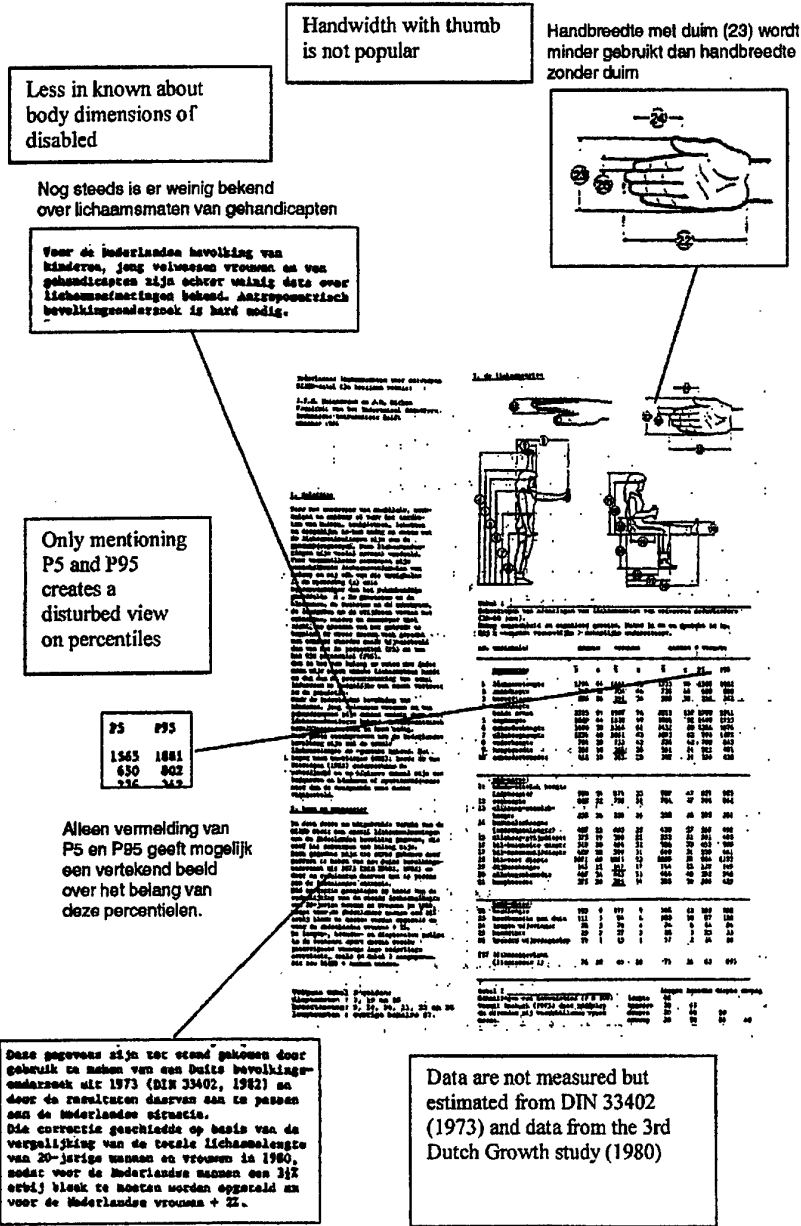


Figure 1: Dined 1984 -front page

598

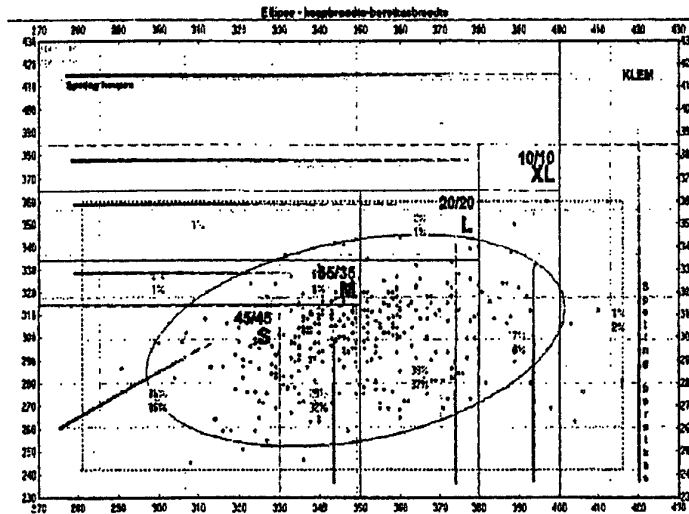


Figure 3: Four sizes of a cart seat are defined based on hip width (vertical) and chest width (horizontal)

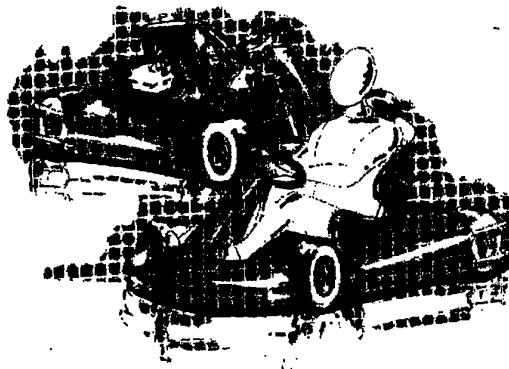


Figure 4: Concept of a the design of a cart in according to figure 3.

* * *

**PRESENTATIONS OF THE WEAR GROUP AT CARS 2002
AND WEAR WORKSHOP**

* * *

K. ROBINETTE. CAESAR : The Emerging 3-D Surface Anthropometry Technology and the Impact on Anthropometric Information Systems.

K. ROBINETTE. Learning to Fit: 3-D Fit Mapping in an Information System.

R. MOLLARD. Shape modeling driven by the product design.

Z. BEN AZOUZ, M. RIOUX, R. LEPAGE. 3D description of the human body shape: application of Karhunen-Loève expansion to the CAESAR database.

Y. LEE. Recent advances in Korean anthropometry.

M. MOCHIMARU, M. KOUCHI. Automatic shape modeling of the foot: towards a database of foot shapes.

J.F.M. MOLENBROEK. Tools for understanding anthropometry.

Y. LEE. WEAR meeting.

J.F.M. MOLENBROEK. Process of wear-ais Proposal.

CAESAR:

The Emerging 3-D Surface Anthropometry Technology and the Impact on Anthropometric Information Systems

28 June 2002

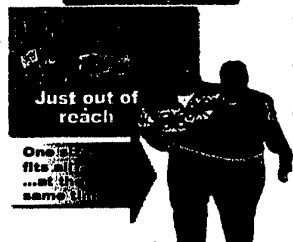


Kathleen M. Robinette
Principal Research Anthropologist
Human Effectiveness Directorate
Air Force Research Laboratory

Overview

- What are we trying to do?
- How was it done in the past and what are the limitations?
- What is the new approach and why do we think it will be successful?
- What does this mean for a world information resource?

What are we trying to do?



- 5th percentile female to 95th percentile male criteria were recently put into a aircraft seat requirements document
- Apparel and equipment engineers continue to design for the average and scale it up and down
- There is NO Easter Bunny, NO 5th percentile female, and NO average man
- We have known these things are not good practices for more than 40 years
- We have the knowledge and information to make the right choices so why are wrong choices still being made?

What are we trying to do?

- Develop on-line world-wide information system for utilizing the latest anthropometry databases in engineering environments
 - the latest anthropometric data from world populations
 - fit and accommodation information
 - analytic and software tools
 - guidance or intelligent agents for using the information effectively

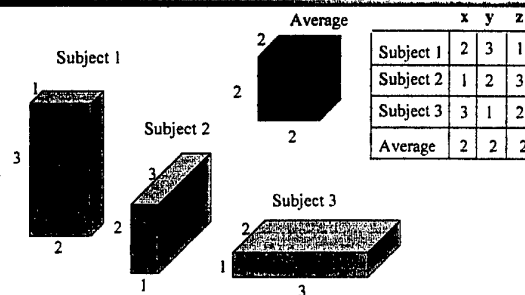
How has it been done?

- Why? Correct information is difficult to find and use
- Must contact an "expert" consultant who searches the most relevant resources available and provides a response
- Just data, not information and not on-line
 - Printed texts with summary statistics (mean, standard deviation and percentiles)*
 - One-dimensional data by survey in spreadsheets on CDs
 - Collections of 3-D scans in original scan form on CDs



* Note this is the wrong thing to use!

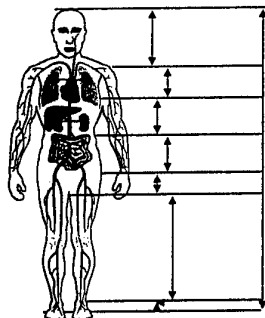
Average is Different From Everyone!



- Average Person? Does Not Exist (Daniels 1952)
- 3-D Average Is Meaningless and Unrepresentative

Percentiles Are Not Additive

3-D 5th or 95th Percentile Person DOES NOT EXIST



Sum of 5th %ile Parts= 136.89 cm
5th %ile Height= 152.50 cm
Difference= 15.61 cm

Sum of 95th %ile Parts= 188.81 cm
95th %ile Height= 173.06 cm
Difference= 15.75 cm



SAMPLE SIZE=3235

*From Robinette and McConville 1982,

What has been done in the past?



Confounding of Size and Shape

Legend:

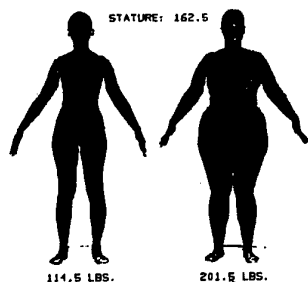
1 = Waist Circ., Preferred 1st trimester

2 = Waist Circ., Preferred, 3rd trimester

3 = Waist Circ., 3rd trimester at 1st trimester location

What is the New Approach?

3-D Provides Difference/
Change Visualization



Why do we think this will be successful?

3-D Identifies Where the Differences are in Addition to Their Magnitude

Radial Difference Map Front



DISTANCE	COLOR
<20 mm	Blue
20-40mm	Green
40-60mm	Yellow
60-80mm	Orange
80-100mm	Red/Orange
>100mm	Red/BlueGreen

Civilian American and European Surface Anthropometry Resource: CAESAR

- First successful 3-D Surface Anthropometry survey
- Represent anthropometric variability of NATO
 - age (18-65), both genders, ethnicity
- 4,431 subjects, more than 13,000 scans
 - U.S. (most people)
 - Netherlands (tallest)
 - Italy (among shortest)

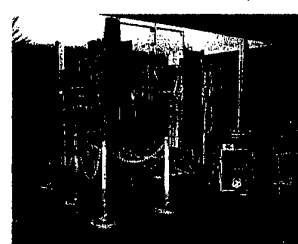


3D Scanners Used

The Netherlands



North America & Italy



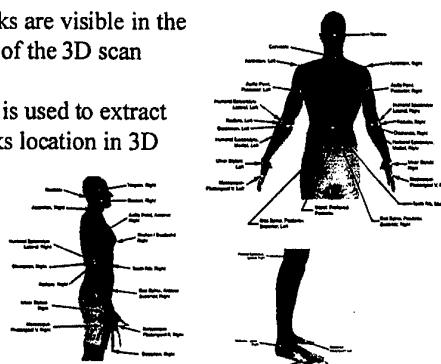
Scan 3 Postures



13

Anatomical Landmarks

- Landmarks are visible in the color file of the 3D scan
- Software is used to extract landmarks location in 3D

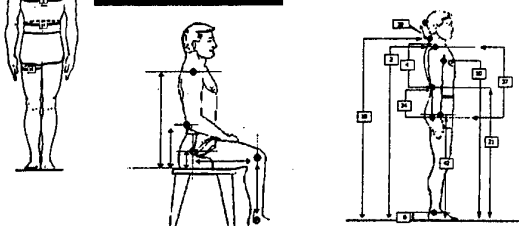


14

Traditional Style Measurements



- Some with traditional tools and postures
- Some scan extracted using pre-marked landmarks and different postures



15

Data Base Size

One Scan	8.0
3 Postures Per Subject	24.0
4,431 Subjects	106344.0
Number of CDs required	164
Cost Per Megabyte	\$ 56.42
Cost Per Subject (\$2.7 million total)	\$ 609.34

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What is the new approach?

- Web-based, comprehensive, international, 3-D shape, fit and performance data
- Easier to access information for a large number and variety of users
- Current, correct solution obtainable for the problem at hand
- Information is immediately accessible...faster answers
- 3-D visualization
- Built-in expert system



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What are the challenges?

- Standardization: 3-D data collection, terminology
- Atlasing and indexing in multiple languages
- New information segmentation/mining
- Characterizing the cognitive processes of an anthropometry expert
- Characterizing huge populations of 3-D objects (human body scans) in a manner that can be effectively searched, mined and visualized
- These are the subject of this session

18

Learning to Fit: 3-D Fit Mapping in an Information System 28 June 2002



Kathleen M. Robinette
Principal Research Anthropologist
Human Effectiveness Directorate
Air Force Research Laboratory

Overview

- What are we trying to do?
- How was it done in the past and what are the limitations?
- What is the new approach and why do we think it will be successful?
- What does this mean for a world information resource?

What are we trying to do?

WEAR: World Engineering Anthropometry Resource

- On-line world-wide information system for utilizing the latest anthropometry databases in engineering environments
- Latest 3D surface and traditional anthropometric data from all over the world
- Fit and accommodation information
- Analytic and software tools
- Guidance or intelligent agents for using the information effectively

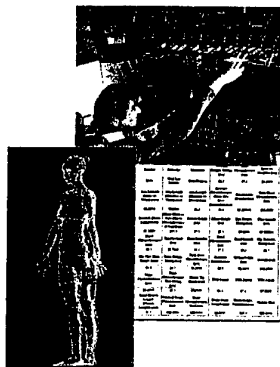
What is Fit Mapping?

- A Fit Map is the Range and Quality of Fit Shown in Anthropometry Space
- Fit Mapping has 2 parts:
 - Surveying the Quality of Fit in Anthropometry Space
 - Calculating and Displaying the Range and Quality of Fit in Anthropometry Space

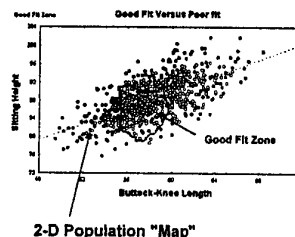


Fit Mapping Survey

- Fit test (with live subjects not electronic models)
- Evaluate fit to determine the point(s) at which the product no longer fits
- Measure the subjects body size at the same time as the fit evaluation
- Measure the spatial relationship between the person and the product
- Measure the product

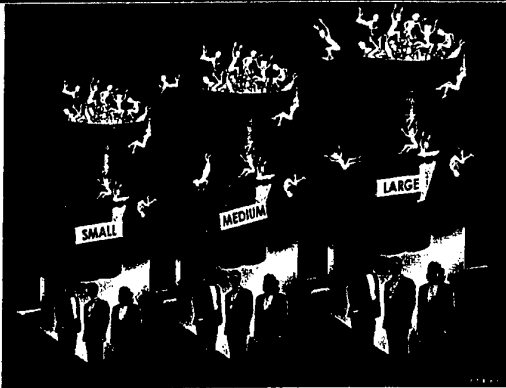


Fit Map Calculation and Display

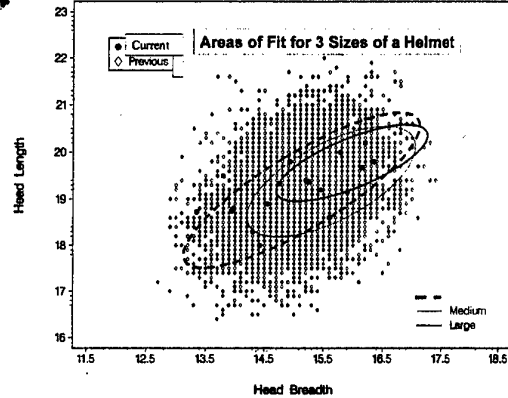


- Using fit survey results group all the subjects into good fit and poor fit categories
- Analyze to determine most important anthropometric variables (e.g. Discriminant Analysis)
- Determine dividing lines between good fit and poor fit
- Draw on the "map" of the Population

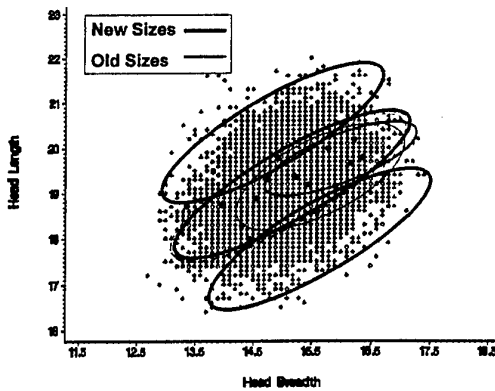
Products Come in Discrete Sizes, Not People



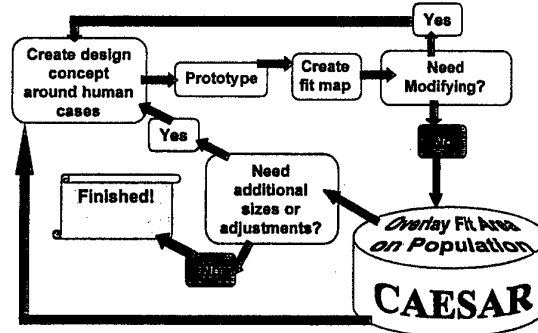
Why Fit Map? Design and Reality are Different



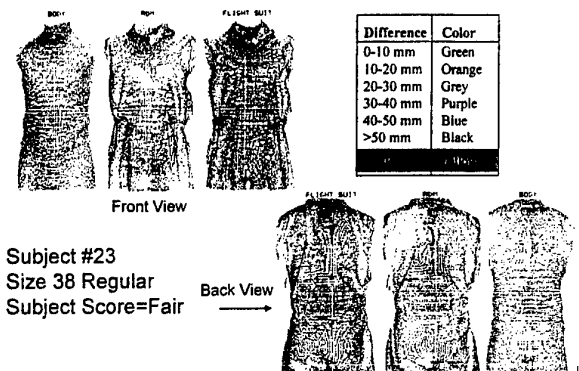
Improved Size Assortment As Dictated By Fit Map



Effective Process

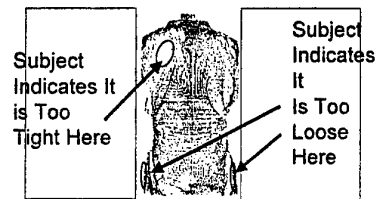


3-D Adds Visualization and Fit Geometry Measurement Capability



3-D Adds Visualization and Fit Geometry Measurement Capability

Example of one observation during fit testing



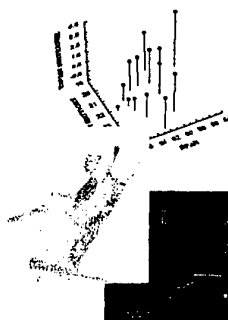
Subject #23
Size 38 Regular
Subject Score=Fair

Subject indicates that all areas except those shown at left fit well

Use Fit Maps to Learn

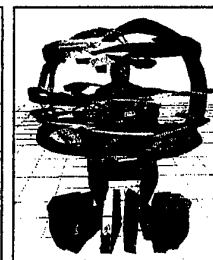
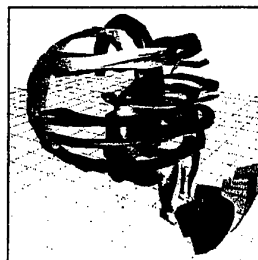
Document Case Histories in 3-D

- Measure person
- Measure system/product
- Measure relationship
- Use successful reach, clearance and system location to learn



13

Document performance zones in 3-D



Lofted motion paths for visualizing and evaluating representative 3D human motion paths, dynamic postures, comparison of individuals to population sample or "standard".
(Duncan et. al. 2000)

14

Summary

- Much can be learned from fit maps for future design
- But **ONLY** if people can find the information and make sense of it!
- Need to determine how to document for an international community
- Need to determine how to mine the appropriate information for the full spectrum of users
- Requires multi-national and multi-disciplinary team

15

References

- DUNCAN, J., Keleher, B., Newendorp, B., Ryken, M., Chipperfield, K., Raschke, U., and Brunsman, M. (2000) Designing for Populations of People Using Tools Describing More of Their Dimensions. *Proceedings of the 14th Triennial Congress of the 2000 International Ergonomics Association* (San Diego, California), August 2000.

16



Université Paris 5
Laboratoire
d'Anthropologie
Appliquée



Shape modeling driven by the product design

Régis Mollard

Laboratoire d'Anthropologie Appliquée
45 rue des Saints-Pères
75270 PARIS Cedex 06 - FRANCE

CARS - Paris - June, 26-29 2002

From size to shape modeling (1)

- Classical (1-D) anthropometric data are available in different databases
- Statistical models were developed according to specific needs :
 - « small » - « medium » - « large » models
 - evolution of morphology based on the increase of stature and weight and the correlated measures
 - sizing methods based on variability of key measures

From size to shape modeling (2)

- Biostereometric (3-D) data are now available on large populations
- Databases are in progress to allow the data processing of both 1-D and 3-D data
- Mathematical methods for shape modeling are developed by many teams

The WEAR project

- Understanding the cognitive processes of anthropometry experts when dealing with such 1-D and 3-D databases
- Identifying a means to computationally replicate these processes
- Characterizing populations of 3-D subjects in a manner that can be effectively searched, mined and visualized

The main issues

- Gathering the existing methods
- Identifying the databases
- Defining the structure of the on-line information system
- Developing data models and software tools

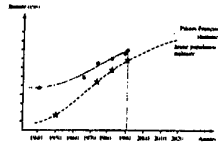
Size and shape modeling driven by the product

Anthropometric data processing (1)

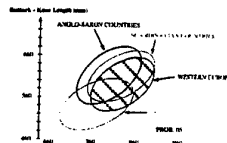
- Statistical modeling of increase of morphology
- Choice of key measures according to the product :
 - ex : seated operator - eye-seat height
 - buttock knee length
- Bivariate distributions to define appropriate small, medium and large models
- Using to define digital human models

Size and shape modeling driven by the product

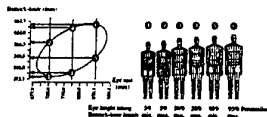
Anthropometric data processing (2)



Evolution of the stature. Mean values compared between two french populations from 1940 to 1991. Prediction up to 2020.



Choice of well-adapted measurements



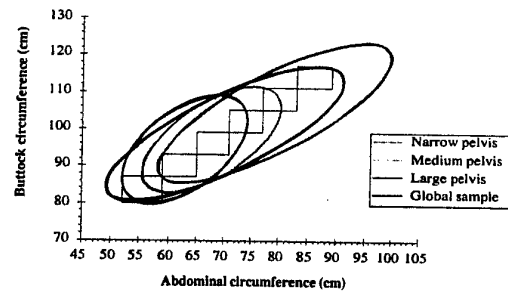
Choice of typical human body models using bivariate distribution. Example to create 5th, 50th and 95th percentiles of ERGOMAN models.



Digital model evaluation

Size and shape modeling driven by the product

Anthropometric data processing (3)



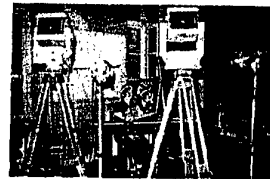
Bivariate distributions according to bicretal index
Plotting of actual sizing system

Size and shape modeling driven by the product

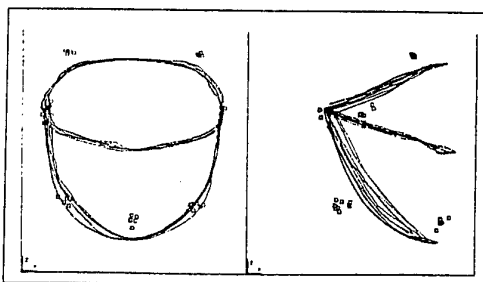
Biostereometric data processing (1)

- Identifying the key information useful to design the product
 - dimensions, angles, curvatures, ...
 - 3-D locations of landmarks and/or reference points
- Defining the constraints : deformability of the material, ...
- Creating geometrical models according to the defined constraints
 - basic : 3-D reference landmarks variations
 - range of variations of anatomical curvatures
 - surface modeling for the concerned areas

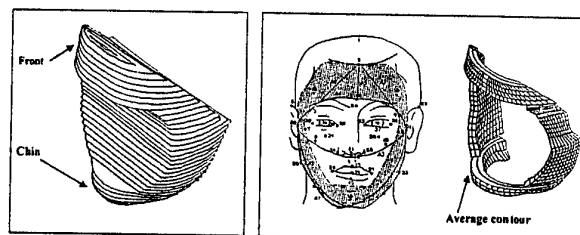
3-D measures of the head



3-D landmarks and anatomical arcs



3-D simplified model of the face

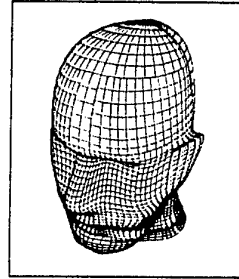


Example of product : a military NBC foreface

Ergonomical evaluations



Model for the design of head equipments



Size and shape modeling driven by the product

Biostereometric data processing (2)

- The result is :
 - different models : from basic one to more sophisticated models
 - using of 1-D and/or 3-D data according to the identified needs

3D Description of the Human Body Shape: Application of Karhunen-Loève Expansion to the CAESAR data base

Zouhour Ben Azouz, Marc Rioux, Richard Lepage

National Research Council of Canada
Visual information technology group

Ecole de technologie supérieure de Montréal
Laboratoire d'imagerie de vision et d'intelligence artificielle

Purpose

Analyze the human body shape variability using the provided 3-D database in order to improve the sizing strategy in the design of many products

A compact description of the human body shape is required

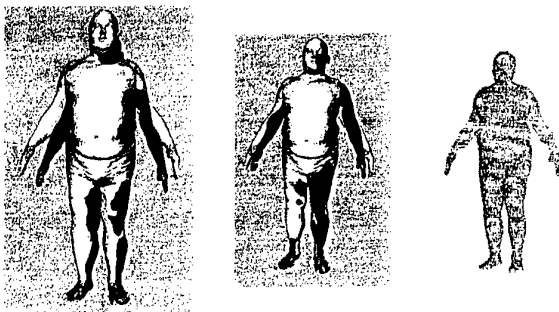
Purpose

- Although 3D scan provides a good description of the human body surface it represents a large amount of data (thousands of polygons)
- The description should provide a faithful reconstruction of the shape

Approach

- Similar to the approach used for face recognition : using karhunen loève expansion (Principal Component Analysis) to extract a set of eigenfaces representing a base of the faces space.
- Extract a set of eigenpersons from CAESAR database : a human body will be described by a set of coefficients representing its correlation with each eigenperson

Data Pre-processing



Karhunen-Loève expansion

$$\Psi_i$$

$$\bar{\Psi} = \frac{1}{N} \sum_{i=1}^N \Psi_i$$

$$\Phi_i = \Psi_i - \bar{\Psi}$$

$$A = [\Phi_1 \Phi_2 \dots \Phi_N]$$

$$C = A^T A$$

Karhunen-Loève expansion

$$\Phi_j \cup \{c_{ij} \cdot \bar{u}_j\} \quad 0 \leq M \leq n$$

$$c_{ij} = \Phi_j \cdot \bar{u}_j$$

6-11

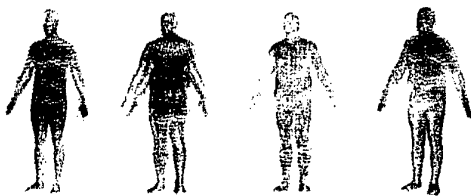
Karhunen-Loève expansion

$$x = \sum_{i=1}^N \lambda_i v_i \quad [0, N-1]$$

$$u_i = \frac{1}{\sqrt{\lambda_i}} \sum_{j=1}^N \lambda_j v_j \quad [0, N-1]$$

$$u_i = \frac{1}{\sqrt{\lambda_i}} \sum_{j=1}^N \lambda_j v_j \quad [0, N-1]$$

RESULTS



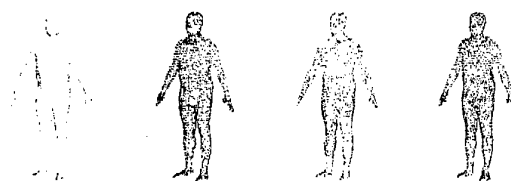
Reconstruction of persons included in the training set



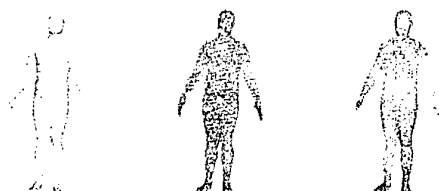
Reconstruction of persons included in the training set



Reconstruction of persons included in the training set



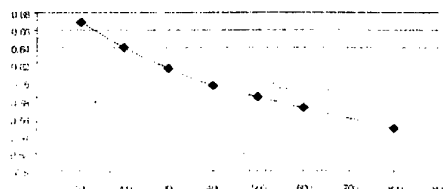
Reconstruction of persons non-included in the training set



Reconstruction of persons non-included in the training set



Variation of the eigenpersons number with the training set size



Conclusion

- The preliminary results show that the Karhunen-Loève expansion is an interesting approach to develop a description of the human body
- The description is compact: ~25000 of polygons reduced to hundreds of coefficients
- Variability due to the hands position

Recent Advances in Korean Anthropometry

28. June. 2002

Youngsuk LEE

Chon-nam National Univ. LEE Y.S

Introduction

• The Measurement of the Human Body

□ Database of Body size

• Physical Features

□ Database of Body shape

Korean Anthropometry

1. Data Collecting

2. Its Applications

3. On-line Information System

Chon-nam National Univ. LEE Y.S

Data Collecting

• 1979 : 6-50yrs, 17,000samples

□ 2D, 117Dimensions

• 1986 : 6-50yrs, 21,000samples

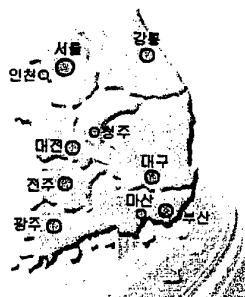
□ 2D, 80Dimensions

• 1992 : 6-50yrs, 8,800samples

□ 2D, 84Dimensions

• 1997 : 1-70yrs, 13,000samples

• 2003 : 2D & 3D, 20,000samples



Chon-nam National Univ. LEE Y.S

Its Applications

• Establish and Update Korean Standards

□ Sizing System: Clothes, Shoes, School Furniture, etc.

• Construction Databases

- • Comparison of the size
- Workplace design
- Furniture Design
- Product Design

Chon-nam National Univ. LEE Y.S

On-line Information System

• On- Line Information System

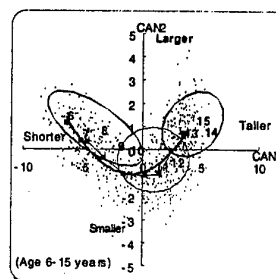
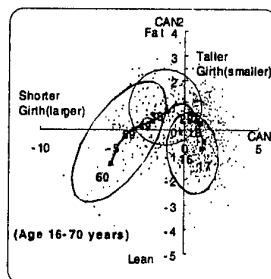
□ 3D Shape and Fitting

• CAD System

□ Automatic Pattern Grading
Easy Order System

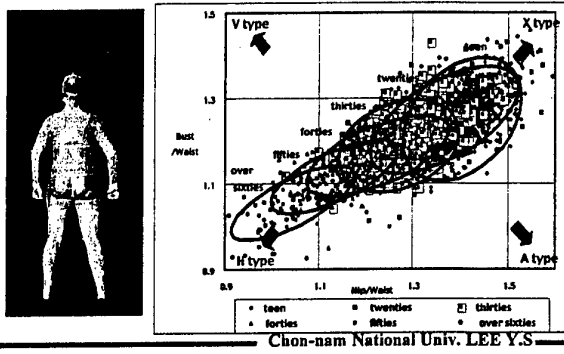
Chon-nam National Univ. LEE Y.S

Body Shape Changes by Age

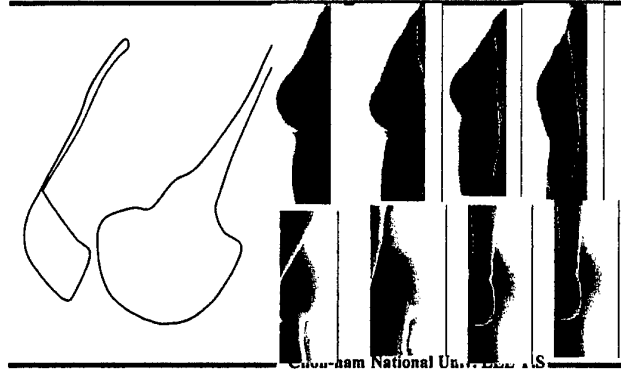


Chon-nam National Univ. LEE Y.S

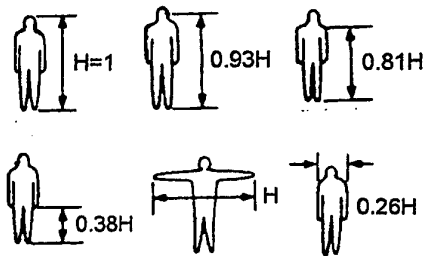
Classification of Body types



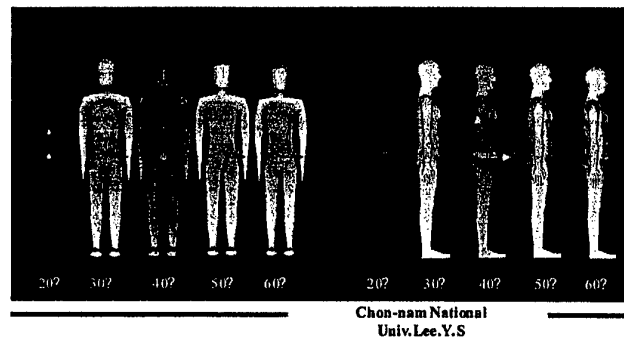
Cup Patterns by Breast Shape



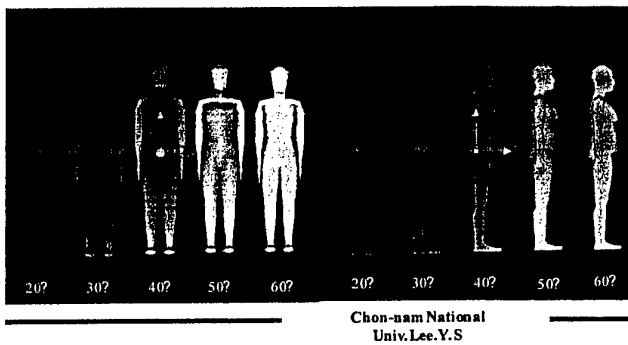
Body Proportions in Korean



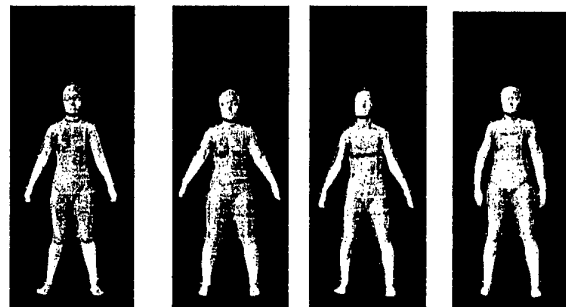
Human Modeling (Korean Man)



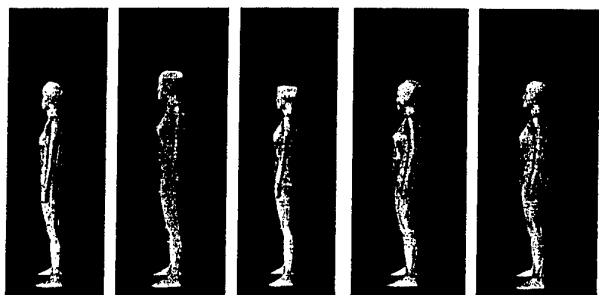
Human Modeling (Korean woman)



Body Shape Comparison in Twenties

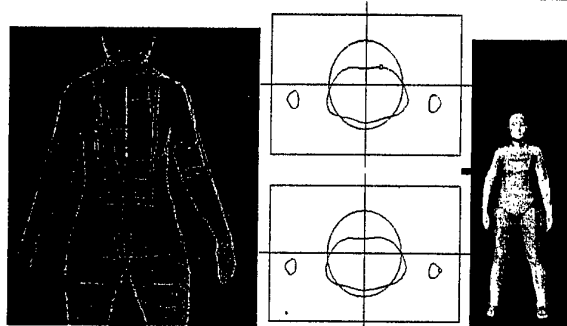


Body Shape Comparison in Twenties(side)



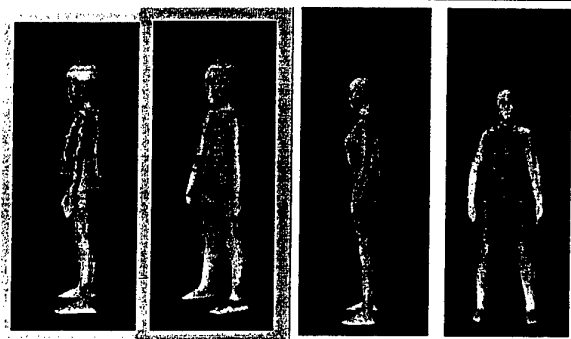
Chon-nam National Univ. LEE Y.S

Body Shape Comparison in Twenties(2)



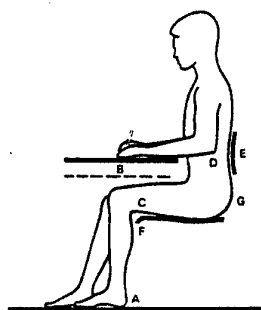
Chon-nam National Univ. LEE Y.S

Body Silhouette Changes



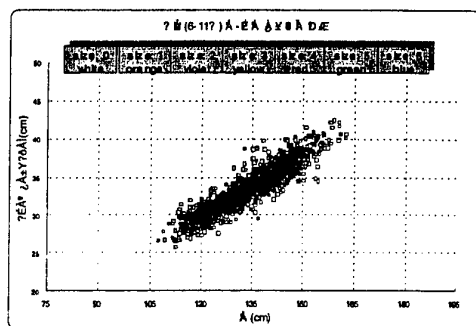
Chon-nam National Univ. LEE Y.S

KS Standard for Student Table Size



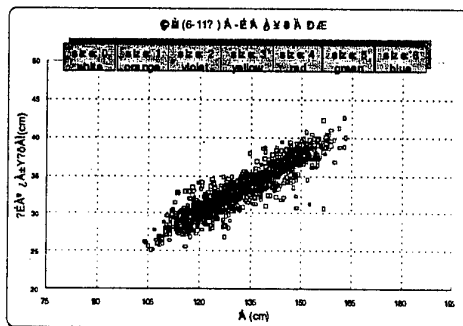
Chon-nam National Univ. LEE Y.S

Size distribution in 6-11yrs boys



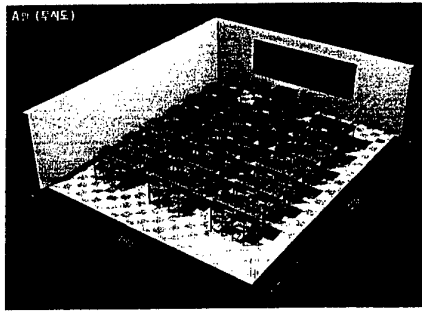
Chon-nam National Univ. LEE Y.S

Size distribution in 6-11yrs girls



Chon-nam National Univ. LEE Y.S

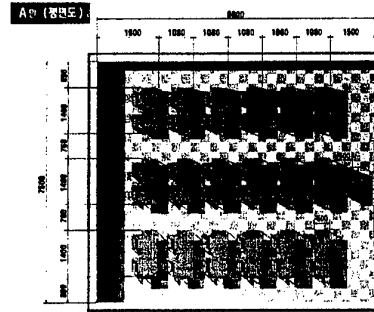
700*500 Table Size(A,36students)



<그림> B 크기 정형(700x500mm) 및 36명 학생용 테이블 배치

Chon-nam National Univ. LEE Y.S

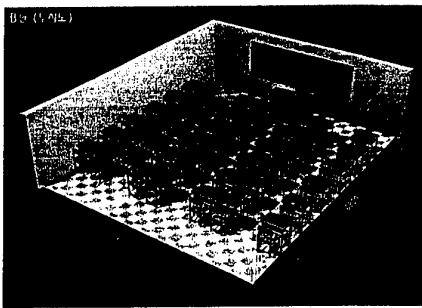
700*500 Table size(A, 36students)



<그림> B 크기 정형(700x500mm) 및 36명 학생용 테이블 배치

Chon-nam National Univ. LEE Y.S

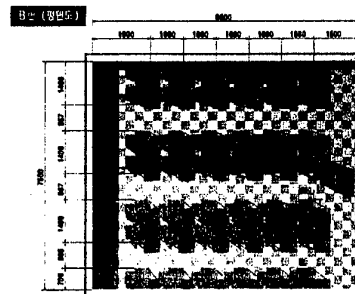
700*500Table size(B, 42 students)



<그림> B 크기 정형(700x500mm) 및 42명 학생용 테이블 배치

Chon-nam National Univ. LEE Y.S

700*500Table size(B, 42 students)



<그림> B 크기 정형(700x500mm) 및 42명 학생용 테이블 배치

Chon-nam National Univ. LEE Y.S

Conclusion

• Anthropometric Data Process

• Develop Data Models and Software Tools

• Clothing Industry

- 2D Pattern Making-Design, Ease, Comfort, Cutting-
- 3D Fitting Test- Dummy-3D Data

• Shoe Industry

- Key Dimensions for Shoe sizing-2D Shoe Pattern
- Shoe Last-3D Fitting-CAD

• Size Grading Technique



Chon-nam National Univ. LEE Y.S



Automatic shape modeling of the foot: towards a database of foot shapes

Masaaki MOCHIMARU, Makiko KOUCHI

Digital Human Laboratory
National Institute of Advanced Industrial Science
and Technology (AIST)

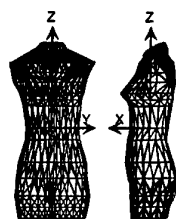
Homologous human shape modeling



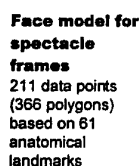
- Scanned data
 - Å Millions of surface data points
 - No anatomical correspondence, verbose
 - Å Dozens of landmarks
 - Too few to represent surface curvature
- Homologous modeled data
 - Å Hundreds/Thousands of data points
 - Same number of data points and same topology
 - Anatomical correspondence
 - Appropriate number of data points
 - Å Application
 - Statistics (Distribution, Average, S.D.)
 - Product customization



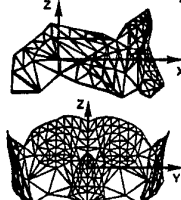
Examples



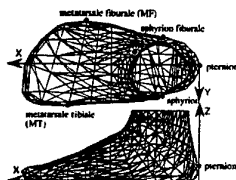
Torso model for a dressmaking dummy
547 data points (1039 polygons) based on 25 landmarks.



Face model for spectacle frames
211 data points (366 polygons) based on 61 anatomical landmarks



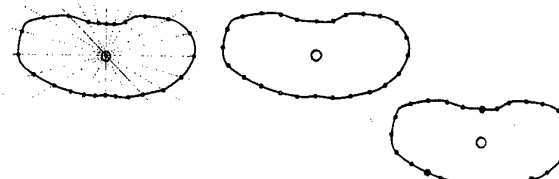
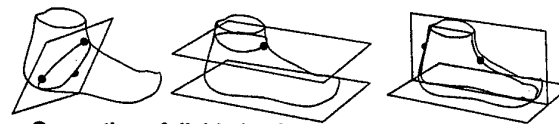
Foot model for shoe lasts
295 data points (586 polygons) based on 9 landmarks



Basic modeling procedures



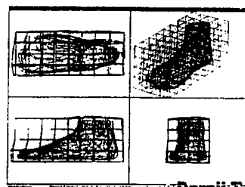
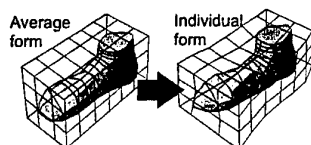
- Generation of a cross section
- Generation of divided points on a cross section



Representation of shape differences



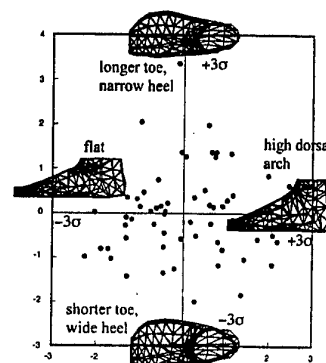
- Representation of individual difference
 - Å Using the Free Form Deformation technique
 - Å Represent with the distortion of the grid
 - Å Calculate the optimal grid distortion from the average shape to the individual shape
 - Å Calculate the shape distance with the grid distortion



Statistics of 3D body shapes



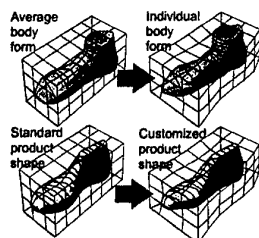
- Statistics
 - Å Shape distance matrix
 - Å Shape distribution map
 - Å Average form
 - Å Standard deviation forms



Deformation of a custom shoe last



- **Provide well-fitting products cheaply and quickly for the consumers located on the end of the distribution**
 - Communicate with digital human models
 - Design with CAD and digital human models



Foot scanner at retail stores



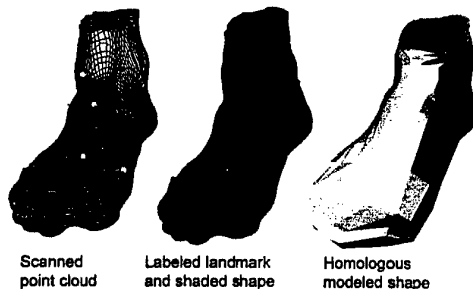
- **Foot scanner INFOOT**
 - ⌚ Low-cost and compact
 - ⌚ Easy operation
 - ⌚ Meas. Duration: 10 sec
 - ⌚ Resolution: 1.0 mm
 - ⌚ 5 landmarks
 - ⌚ 17 foot dimensions
- **Accuracy**
 - ⌚ Dimensions by INFOOT
 - ⚡ Dimensions by trad. method
 - ⌚ MAD: within 1.0 mm



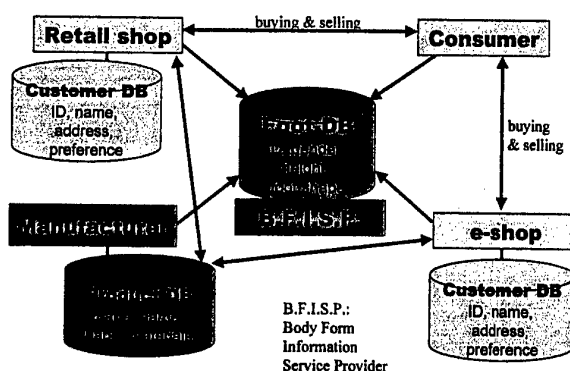
Automatic shape modeling



- **Marking landmarks is the manual procedure**
- **Detecting marker seals and labeling are automatic**
- **Homologous shape modeling is automatic**



A large foot database




Advantages

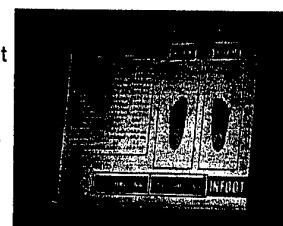


- **3D anthropometric survey with dispersed scanners**
 - **A** Foot scanners are located retail shops
 - **A** Measurers: Shop clerks
 - **A** Subjects: Customers
 - **A** Small budget, large number of data
- **Happiness**
 - **A** Retail shops: sell well & get customers' information
 - **A** Customers: get well fitting shoes
 - **A** Manufacturers: design better fitting shoes
 - **A** Service Providers: sell statistic information
 - **A** Researchers: get large number of data

Problems



- **Quality control**
 - Measurement equipment
 - Accuracy testing
 - Measurement protocol
 - Controlling the measurer's skill (landmarking)
 - Controlling the subject posture and gaze
 - **Biased sampling**
 - Lack of information
 - Birthplace, ethnic group, social class, occupation ...
 - Complement survey by a public organization
 - Males, Elder people, Lower social class ...
- 



Proposal of 3D anthropometric DB



- **With homologous models**

- Å Statistics of 3D body forms are available.

- It is useful for reconsidering the sizing system of mass produced products.

- Å Product customization would be possible using the morphological individual difference (FFD grid)

- **By dispersed scanners**

- Å Large amount of body form data can be measured.

- It is not needed a big national project.

- Å Quality control and complement sampling are required.

Tools for understanding anthropometry

Dr Johan Molenbroek
Assoc Prof Engineering
Anthropometry
TUDELFT

Industrial Design Engineering

30 years of design education

The present (May 2002)

- 1800 students

- 180 in the final stage

Educational system after 1 September 2002 with 500-1000 hours of ergonomics

- 3 years bachelor after high school
- + 2 years master

june 2002

CARS 2002 WEAR PARIS

Industrial Design Engineering



- This recent new building serves 1800 students and 300 staff (50 fte edu)
- 3 years Bachelor IDE
- 2 years Master IDE
- 180 masters finishing yearly
- 90% within industry in product development
- 10% in own research project

june 2002

CARS 2002 WEAR PARIS

Industrial design engineering

- Concept of ide is to integrate four disciplines as user centered design to create products for people
- + Engineering
- + Ergonomics
- + Design
- + Product innovation and marketing
- So every creation is continuously tested with simulated and real users during the design process by iteration

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CARS 2002 WEAR PARIS

Industrial design engineering



- Target groups can be:
- Handicapped
- Elderly
- Adult male or female
- Children
- Ethnic minorities

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The growth of using anthropometry

- 1D
 - Percentiles of 1 key dimension
- 2D
 - Ellipses with 2 key dimensions
- 3D
 - We need easy to access tools to describe the density of shapes of key surfaces in 3d space in the context of man-product-interaction (fit)
- 4D
 - We need also tools to describe the changes in time of this fit (3d space)
- 5D
 - And maybe other dimensions to follow like temperature, pressure, etc

june 2002

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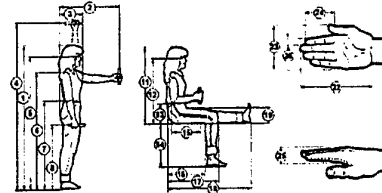
One dimensional anthropometry

- Looks easy but solves only simple problems
- We used tables of USA Flying Personnel 1954, DIN 33402 and online databases like ERGODATA or Anthrokids or off line databases like People Size or Childata, Olderadult
- DINED → Made in Holland

june 2002

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dined 1984-2002



An estimation of 27 body dimension of Dutch adults
Which is used as a national standard since 1986
Mean 1794 mm for aged 20-60 is still valid but limited in use

june 2002

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Dined after 16 years usage

Negative

- 1D
- To much trust
- Data needs update
- No data about children
- No data about elderly
- Easy to misuse

Positive

- Very popular
- Widely distributed
- Free of costs
- On the web
- Interactively
- Became national standard
- Easily to use

june 2002

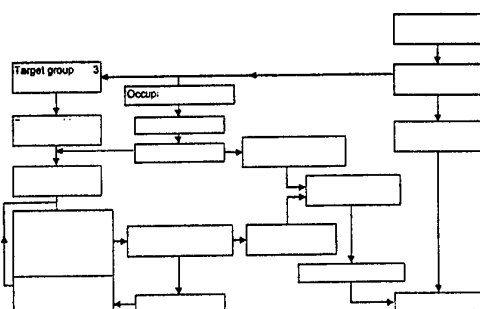
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AIS



Tools for 1 D Anthropometry

Anthropometric design proces



june 2002

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User-product-interaction for a chair

P1				
A1				

june 2002

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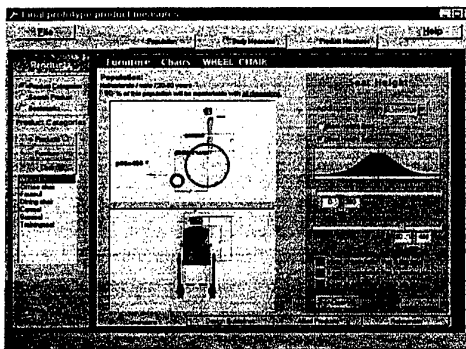
Once or continuous adjustable

- Once adjustable
- Continuous adjustable
- Disadvantage adjustability
- Proper adjustability
- Kitchen/ lenght of a Levi pair of trousers
- Seat height office chair
- Put it wrong
- More expensive
- Feedforward
- Feedback
- Right bounderies

june 2002

CARS 2002 WEAR PARIS

Adjustment of seat height



june 2002

ELLIPS

This tools was made in 1990 after studying Anthropometric Source Book from ARP 1978 and the statistical handbook of Sokal

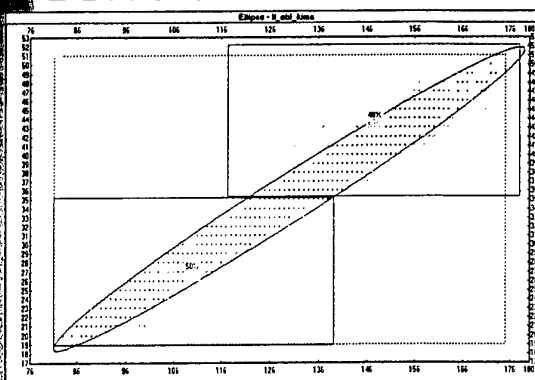
Two dimensional anthropometry

- Gives insight in correlation
- Gives insight in consequences for related body dimensions
- But only in 2D windows
- To understand 3D problems tools are still needed to switch easy from window to window

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2 Dimensional



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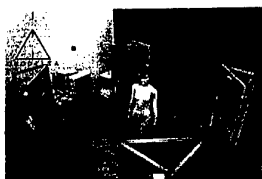
Three dimensional anthropometry

- We not only need tools to cad products, like pro engineering or solid works
- We need also tools to study the man-product-interaction (fit) for different populations
- Then the designer can decide if s(h)e needs adjustability (office chair) or more types of the product (school furniture;shoes)
- But first we need to increase the availability of the current 3D data and especial tools that show the variation in the human body form within a population; perhaps such as the USA-NIH stimulates data sharing (Vannier, et al., 2002),
- The approach of Mollard (2002) with key dimensions look similar with my above mentioned thoughts, and the homologous shape modeling (Mochimaru and Kouchi, 2002) and the Web3D viewer of Ressler and Wang (2002) seem also promising steps

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3D-stereophotogrammetry



- 12 digital camera's
- Grid projection
- Automatic calibration
- New in anthropometry ?

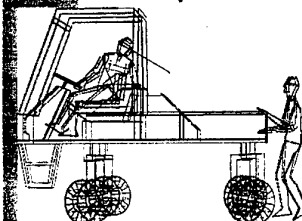
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Digital models

adaps

safework



Medical Equipment Design



june 2002

CARS 2002 WEAR PARIS

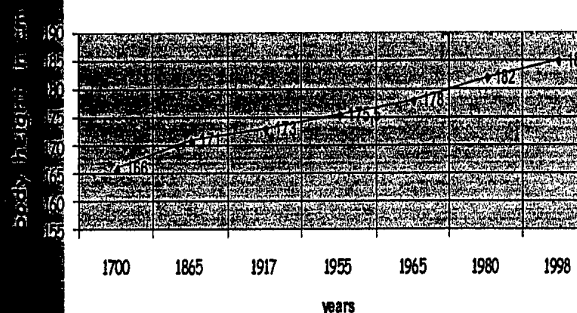
Four dimensional anthropometry

- We can visualize growth as it is, a increase in volume and mass,
- We can also visualize the decrease in height, volume and mass as it happens in elderly or in diseases
- We could emphasize those key surfaces which should have ease or no ease in using ie when designing prostheses, clothing etc
- Another slow but 4th dimension might be the secular trend which is essential for products with a long life like public transport or houses

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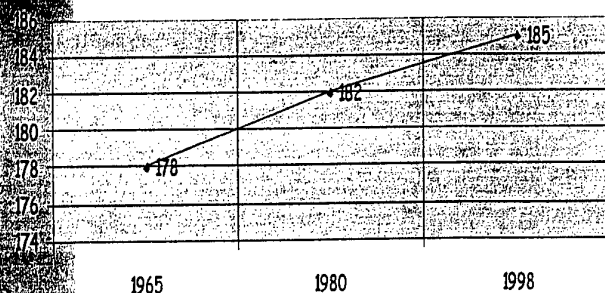
secular trend Dutch body height
average 1.5 mm per year



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Dutch secular trend 1965-1995
2.7-1.8 mm per year



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Anthropometry vs Medicine

- | | |
|---|--|
| ■ Concentrates on variation of human body characteristics like form and dimensions of healthy populations primarily to optimize the man-product-interaction = fit | ■ Concentrates on human body characteristics including form and dimension for diagnoses of pathology of the non-healthy human to cure his/her diseases |
| ■ Subjects = test persons | ■ Subjects= patients |
| ■ Area: 1=prevention
2=care 3 =cure | ■ Area: 1=cure 2= care
3=prevention |

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Anthropometry and Medicine

- Both are contributing to the improvement of health and interested in high tech tools to show the details human body form and dimension
- It seems effective to share the knowledge in each field like is done during this CARS conference

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- Thank you for your attention
- Further information about our work is on www.io.tudelft.nl/research/ergonomics or/build/

june 2002

CARS 2002 WEAR PARIS

WEAR MEETING

Paris, 25 June
Young-Suk Lee

9/09/03

Chon-nam National Univ. LEE Y.S

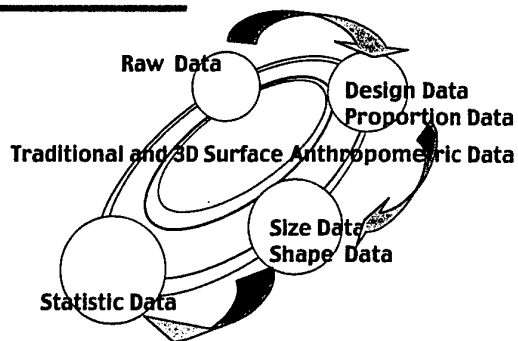
Objective

1. Data Models
2. Software Tools
3. On-Line Worldwide Information
4. Data Sharing
5. Database Standardization
6. Maximize Utility

9/09/03

Chon-nam National Univ. LEE Y.S

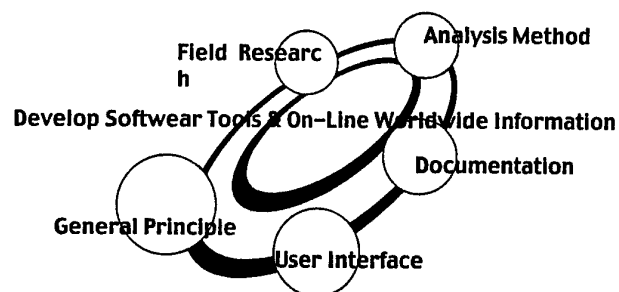
Data Models



9/09/03

Chon-nam National Univ. LEE Y.S

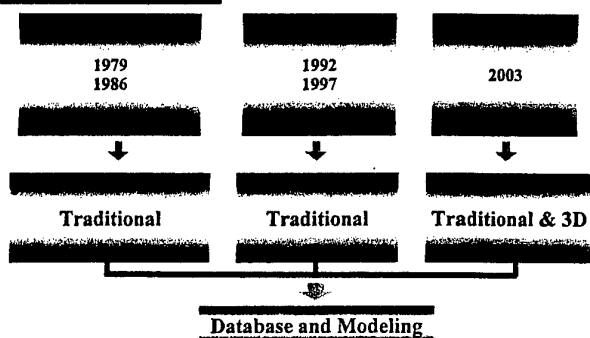
Software Tools



9/09/03

Chon-nam National Univ. LEE Y.S

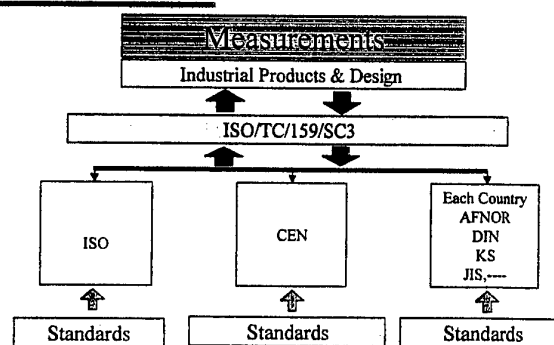
Data Sharing (Korea)



9/09/03

Chon-nam National Univ. LEE Y.S

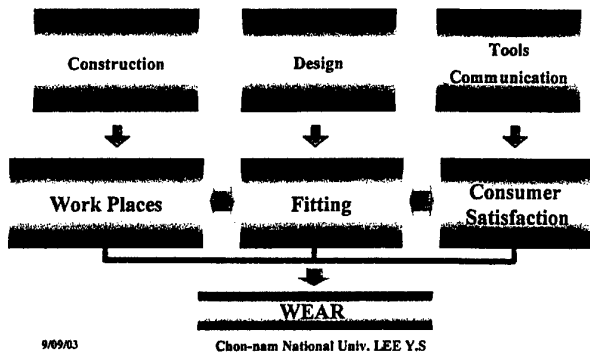
Database Standardization



9/09/03

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Maximize Utility



Korean National Survey

Standardization

Applications

Utilities

9/09/03

Chon-nam National Univ. LEE Y.S

Character Modeling

- Body Size
- Body Shape
- Growth Rates

9/09/03

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Data Applications

- Standardization
- Sizing Systems- Clothing, Headwears, Optical frames, Innerwears, Built-in Furnitures, Medical Images,etc.
- Dummy

9/09/03

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Comparison

- Race
- Age
- SW Development
- Standardization

9/09/03

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Research Design

Research Scope

Participants

Research Contents

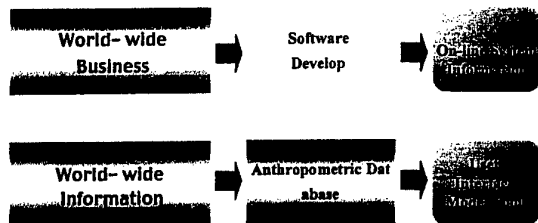
Limitations

WEAR
Establishing

9/09/03

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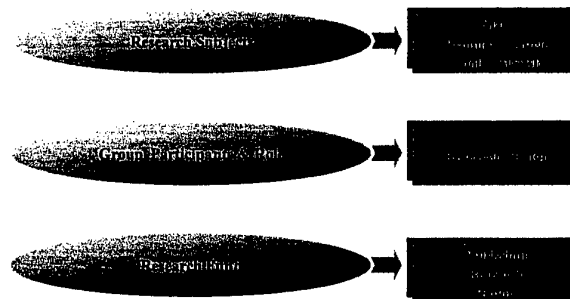
WEAR Project



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Chon-nam National Univ. LEE Y.S

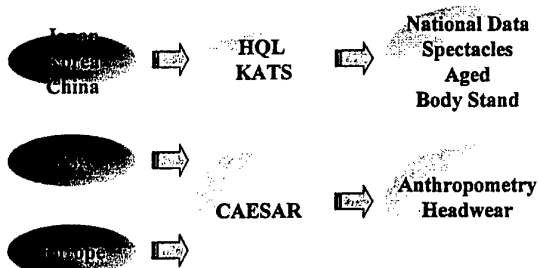
Our Issues



9/09/03

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Research Reports



9/09/03

Chon-nam National Univ. LEE Y.S

Group Management

Data Management
(Age, Nation, Items, Body, 3D)



Research Management
(Statistics, Web, Tools)

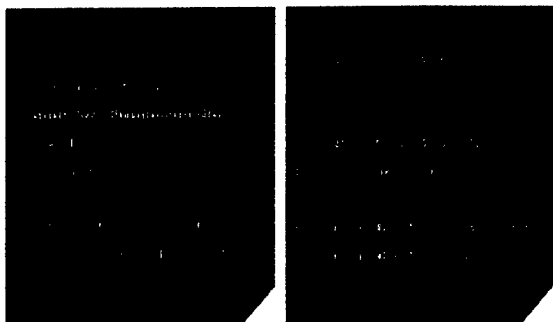


Result Management
(How we can provide it)

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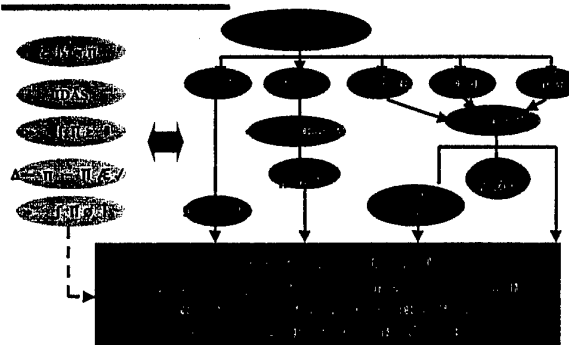
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9/09/03

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9/09/03

Chon-nam National Univ. LEE Y.S

Process of wear-ais Proposal

Johan Molenbroek

Formulate target group of users

- Researchers in anthropometry
- Designers(and students I design/engineering with limited knowledge about anatomy and statistics)
- Laymen (journalist, students ..)
- --
- --

Programme of requirements and wishes (1)

- Easy to use without knowledge in anatomy and statistics
- Not bothering for experts in anthropometry
- Stimulates users to follow certain sequence in steps in their process of decisions
- Shows how to combine measurements
- Shows how to combine populations
- Shows how to include additional factors like clothing, shoes or personal equipment
- Shows where a-data are located

Programme of requirements and wishes (2)

- Shows the price
- Software is platform and browser independent (ie java applet on www.ais.org?)
- Data have a quality indicator (ie * or ** or ***)

Quality indication

- ***
 - Raw data and statistics available ; population is well described
- **
 - Mean, sd and r and n are available; population is well described
- *
 - Good estimation; population is well described

Actual design of ui(proposal)

- Master student of Delft/IDE
- Tutored by Johan/Regis
- Kathleen acts as the assignment controller
- About 5 in between reports during 6 months starting after summer 2002
- Server: own website www.ais.org hosted by private company costs about 100 euro/dollar per year depending on volume of data

Comparison with lookalikes

- AIS
- IVEO on www.dined.nl/iveo
- EIS on www.dutoh60.io.tudelft.nl
- www.io.tudelft.nl/research/ergonomics/build/dined
- 1995 window based
- 2002 Sql database, apache
- 2000 Java applet
- 2002Flash browser shows quick and easy 1DA

* * *

ANNEX

* * *

- Minutes of the meeting in Dayton-Ohio. September 17, 2001.

WORLD ENGINEERING ANTHROPOMETRY RESOURCE (WEAR) MEETING
17 SEP 2001
DAYTON, OHIO

This meeting was planned to include many participants but due to the events on 11 September only a few were able to make it. The participants invited to the meeting were:

Sherri **Blackwell**, Sytronics Inc., Dayton, OH, USA
Lee Young Suk, Chonnam National University, Gwangju, South Korea
Makiko **Kouchi**, Digital Human Laboratory, National Institute of Advanced Industrial Science and Technology, (AIST), Tokyo, Japan
Masaaki **Mochimaru**, Digital Human Laboratory, National Institute of Advanced Industrial Science and Technology, (AIST), Tokyo, Japan
Johan **Molenbroek**, Lab. for Anthropometric Ergonomics, Delft University of Technology, Delft, The Netherlands
Regis **Mollard**, Laboratoire d' Anthropologie Applique'e Universite' Rene' Descartes, Paris, France
Eric **Paquet**, National Research Council of Canada, (NRC), Ottawa, Canada
Sandy **Ressler**, National Institute for Standards and Technology (NIST), Maryland, USA
Marc **Rioux**, National Research Council of Canada, (NRC), Ottawa, Canada
Kathleen **Robinette**, Human Interface Technology Branch, Air Force Research Laboratory, (AFRL), WPAFB, Ohio, USA
Michael **Vannier**, Dept. of Radiology, University of Iowa, Iowa City, Iowa, USA and the National Institutes of Health, Bethesda, Maryland, USA

It was intended that these, or a subset of these, people who comprise a steering committee for the effort.

The actual attendees were:

Blackwell, Sherri	Sytronics, Inc.; Dayton, Ohio, U.S.A.
Daanen, Hein	TNO Human Factors Research Institute; Soesterberg, the Netherlands
Kouchi, Makiko	Digital Human Laboratory, National Institute of Advanced Industrial Science and Technology; Tokyo, Japan
Mochimaru, Masaaki	Digital Human Laboratory, National Institute of Advanced Industrial Science and Technology; Tokyo, Japan
Robinette, Kathleen	Human Interface Technology Branch, Air Force Research Laboratory (AFRL); Wright-Patterson Air Force Base, Ohio, U.S.A.

Robinette opened the meeting with introductions, and handed out a rather obsolete agenda, and a short description of the goal(s) of the meeting. This description is attached as Appendix A. **Robinette** said the Air Force Research Laboratory has a new program to develop an information system for anthropometric data. This would be a basic information system to be developed over five years. One of her goals is to bring people together now to talk about the issues and to develop something that can become a multinational shared resource.

This was followed by presentations by **Kouchi**, **Mochimaru**, and **Daanen**. Synopses of these presentations and the accompanying discussions are attached as Appendix B. There were three main areas of discussion during the meeting: 1) WEAR Vision, 2) Issues, and 3) General Business. Each of these areas are summarized below.

WEAR VISION: What do we want WEAR to be?

An outline of a concept of the contents of WEAR was drafted. It is below:

WEAR Contents

- 1) Raw anthropometry
 - a) Resident in system
 - b) Pointers to non-resident data (possibly to data owners for purchase)
 - c) Maybe combination (resident and pointers)
- 2) Tutorials on how to use the resource
 - a) Data Collection tutorials
 - Format quality control
 - This would be where quality control stds go. Conform to ISO stds too.
 - b) Application (use) tutorials
- 3) Product Information (These are products being designed using anthropometry.)
 - a) Product properties
 - b) Concept of fit - how does it need to fit to be considered a good fit
 - c) Fit mapping data (A Fit Map is a visualization and/or set of algorithms which indicates- who fits what, who doesn't fit what.)
 1. Raw data from fit mapping surveys
 2. Fit maps (optional)
 - d) Anthropometric design data
 - What models or forms were used to create the product, (for example, 30 head forms were used to create a spectacle)

ISSUES

1) Data Standards/Quality Control: The question discussed was if someone has a data set, how do we "clean" it or do we accept it as is? The 3-D HQL data from 1992, for example, is not in a very useful form as it is. One person said, we should clean data immediately following data collection, however, it should at least be cleaned before it becomes a part of WEAR. Requiring clean data, in a WEAR format may help to establish a standard.

Decision: Must establish data standards and require the data to meet the standards before inclusion in the resource. Data in the resource must be of good quality and must be repeatable.

2) Data Availability and Ownership: There are going to be many issues in this area. For now it was noted that some data can be resident within the resource to be publicly available, and other data can be available through the owners via links.

3) Language: This issue is what languages should be used in a multinational resource. Everyone agreed that there will need to be several languages used. Those discussed were:

- a) Japanese: Many small Japanese firms do not have any English-speaking employees. **Kouchi** suggested that she could assist with either the translations or with the small Japanese firms because anthropometry would be difficult to translate through a normal translator.
- b) French: This is a widely spoken international language and it may be a Canadian law that the information be in both English and French
- c) Korean: English does not seem to be widely spoken in Korean companies. Perhaps **Lee** can offer help as **Kouchi** has offered for Japanese.
- d) English: This is necessary for the US funded effort. **Daanen** indicated that nearly everyone in The Netherlands also speaks English.

4) Security: This was not actually discussed much. The issue is how to let people add data and still protect the integrity of the site(s).

5) Use of Medical Images (Include? Link?): We discussed this issue but didn't feel the right people were present to really answer this questions. Medical images and collections are so huge they may be out of the scope of this resource, although there may be some types that might be useful. Do we want to include these image types? How much medical imaging (if any) do we want to include? Subsurface information is useful for engineering anthropometry, and for biomechanical modeling. We would all like to hear from **Vannier** on this subject. We decided we should continue this discussion on-line and include **Vannier**.

6) Secular Trends: **Daanen** made a case to include secular trends in the data base as raw data, rather than just having reports or tutorials on it. He indicated that these trends had a big impact in The Netherlands. Using old data resulted in poor accommodation for large segments of the population. (No pun intended ☺.) These trends are tracked in The Netherlands, and in the US, at least, and possibly in many other countries. **Kouchi** indicated that if we only include a tutorial, the user may miss this and secular trends are very important. (Robinette here: I have to agree...I never read the manuals unless I get really stuck.) **Daanen** indicated we should have a secular trend for stature and for weight (mass). **Robinette** agreed that secular trends are very important, but was concerned about the methods to calculate and their reliability. **Daanen** indicated there is a whole society devoted to just secular trends. This issue was not decided, but warrants further investigation. All agree that they are needed. The issue is how and where to include them. Perhaps consulting with the society on secular trends can help to resolve.

7) Workshops: **Daanen** suggested that workshops are also a good idea, and can be useful in lowering the learning threshold.

- a) Workshops require a sponsoring organization to maintain the resource and to offer the tutorials (workshops) if workshops are to be held on an on-going basis.
- b) One alternative may be to try to get universities to offer workshops as part of a course. We should look into getting a resource (university) to do this.
- c) **Daanen** commented that user groups learning to use the resource do not have to be WEAR-sanctioned events.
- d) **Kouchi** suggested that another possibility was a video tutorial.
- e) **Robinette** offered AFRL's "Anthropometric Accommodation in Aircraft Cockpits" compact disk (1999-2000) as an example of a video tutorial.

General Business

1) Organizational Structure: The question is how to organize this so that we can get things moving and get everyone involved who may want to be. The recommendation was to have two groups, 1) a steering committee and 2) a users/scientists group. The steering committee would specify rough product concept. The users and scientists would help the steering committee refine the product concept. The current list of invitees would make up the steering committee.

2) CoData: **Robinette** distributed some information given to her by **Ressler** about an organization called CoData. CoData has been in existence since the 1960s, with the purpose of facilitating the exchange of scientific data. It was thought that CoData could possibly act as an umbrella and facilitating organization for WEAR. CoData coordinates multinational data projects. It could be an organization that handles administrative functions, arranging meetings, publishing proceedings etc. for the effort. Or possibly coordinates users/scientists participation. Some information about CoData from their website is attached as Appendix C.

- 3) E-Mail Lists (Listservs): We wanted to have a listserv or mailing list for each of our 2 groups. Who should host the listserv(s). **Robinette** can easily create one. Are there any other ideas about it?
- 4) How to Get Users Involved: Who should be involved and how to we get them interested?
Approach branch organizations to test interest
SAE
ASTM
Eurotex
Furniture branch
Before contacting users need to have: 1) Concept of what WEAR is, 2) Idea of how people would be involved. 3) Who would do what and when?
- 5) Specialist Meeting: A suggestion was made to have a specialist meeting with CoData possibly organizing the meeting and publishing the proceedings. We, the steering committee, would be the specialists and we could invite some others. The audience would be other users and scientists. **Nahum Gershon** and **Pierre Boulanger**, two people known to some of us, participated in the CoData Conference last year. We could ask them what they think of the organization for this purpose.
a) WEAR participants would have anthropometry expertise
b) CoData would collate information, as well as provide expertise on topics such as international law, etc.
How soon would we want the specialist meeting?
- 6) Next Meeting(s): Where and when should the next meeting be? Any volunteers or suggestions? Should we have it or a session at next year's CODATA conference. (29 Sept-3 Oct 2002 in Montreal)
- 7) Funding: **Robinette** has some funding to get a US Air Force Information System started and demonstrated. She can also get some funding for workshops and conferences held in Europe or Asia and will have some travel funding for some non-government European and Asian travelers to Dayton, Ohio USA. We will need additional funds to support making WEAR an international, commercial product, with non-US Air Force applications. We will also need additional funds to complete WEAR. The idea is to work together to help each other attract funding. This brings up the next issue.
- 8) How to Sell the Concept: **Kouchi** - what do potential customers get out of it? Why should anyone use it? Also, what do collaborators get? These are good questions and we need to prepare answers. Some discussed were:
Customers:
- can get data for less
- can find data easier
- should there be a membership fee for the data or system access?
Collaborators:
-should there be a membership fee to be on list serv?
-they get input into design
- 9) As a side note: **Robinette** will have a final cost benefit analysis report for the USAF information system by the end of September. (The draft has been reviewed and a few final changes are being made.) This will be available to anyone interested after she has received approval for public release.